

New Hipparionine (Equidae) Remains from Dhok Pathan Formation of Siwaliks, Pakistan

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Abstract.– New hipparionine remains from the type locality of the Dhok Pathan Formation are described here. The studied material consists of isolated dental elements originated from Siwalik type locality, known for the presence of Late Miocene mammalian remains. The described fossils show the morphological features of the Siwalik hipparionine and according to the results of the present work this material was assigned to two species *Cremohipparion antelopinum* and *Sivalhippus perimensis*. The Late Miocene Siwalik hipparionines are common, nevertheless these new findings seem to be significant contribution.

Keywords: Perissodactyl fauna, *Hipparion*, *Sivalhippus*, Miocene, hipparionine horses.

INTRODUCTION

The Mio-Pliocene fossil record of the Siwalik Hills in Pakistan yields abundant material of hipparionine equids. This material has been intensively investigated over the last 150 years. The hipparionine are abundantly found in the Middle Siwaliks and are considered to be a biostratigraphic indicator of the Late Miocene to Early Pliocene deposits of Pakistan (Barry *et al.*, 2002; Badgley *et al.*, 2005; Naseem *et al.*, 2009; Wolf *et al.*, 2013).

The systematic study of the Siwalik hipparionines was carried out by Owen (1846), Falconer and Cautley (1849), Gaudry (1873), Lydekker (1877a, 1877b, 1883, 1884, 1885, 1886), Matthew (1929), Colbert (1935), Hussain (1971), MacFadden and Bakr (1979), Woodburne and Bernor (1980), Hussain and Bernor (1984), Bernor and Hussain (1985), Bernor *et al.* (2010), Wolf *et al.* (2013) and Khan *et al.* (2011, 2014). These authors have suggested that the presence of hipparionine in the Old World resulted from the dispersal of one monophyletic group or species of *Hipparion* (e.g., Forsten, 1968; Hussain, 1971). Subsequently, it appeared that more than one hipparionine group (i.e., a few genera) dispersed into the Old World during the later Miocene and a few evolved endemically (Wolf *et al.*, 2013).

The described specimens in this article are recovered from the outcrops nearby the Dhok Pathan village (Lat. 33° 07' N; Long. 72° 14' E), which is the type locality of the Dhok Pathan Formation of the Middle Siwaliks, located in the Potwar Plateau of Northern Pakistan. The detailed geography and geology of the type locality is provided in Khan *et al.* (2010). The Formation belongs to Late Miocene-Early Pliocene. The Dhok Pathan fossil site is located at 65 km NE from the Chakwal city and is extremely rich in fossils (Barry *et al.*, 2002; Khan *et al.*, 2010). The studied area is palaeontologically relevant and particularly abundant in equid specimens. This documentation provides us a great help to understand the characters of the Siwalik hipparionines. The aim of this study is to describe the new hipparionine remains from the Pakistani Siwaliks. The terminology (Fig. 1) and taxonomy follow Wolf *et al.* (2013).

The specimens are curated and housed in Dr. Abu Bakr Fossil Display and Research Centre, University of the Punjab, Lahore, Pakistan.

Institutional Abbreviations: PUPC, Punjab University Paleontological Collection, Lahore, Pakistan; AMNH, American Museum of Natural History, New York, USA; BMNH, British Museum of Natural History, London; BSM, Bayerische Staatssammlung Munchen, Germany; GSI, Geological Survey of India; PC-GCUF, Paleontological Collection of Government College University Faisalabad, Pakistan.

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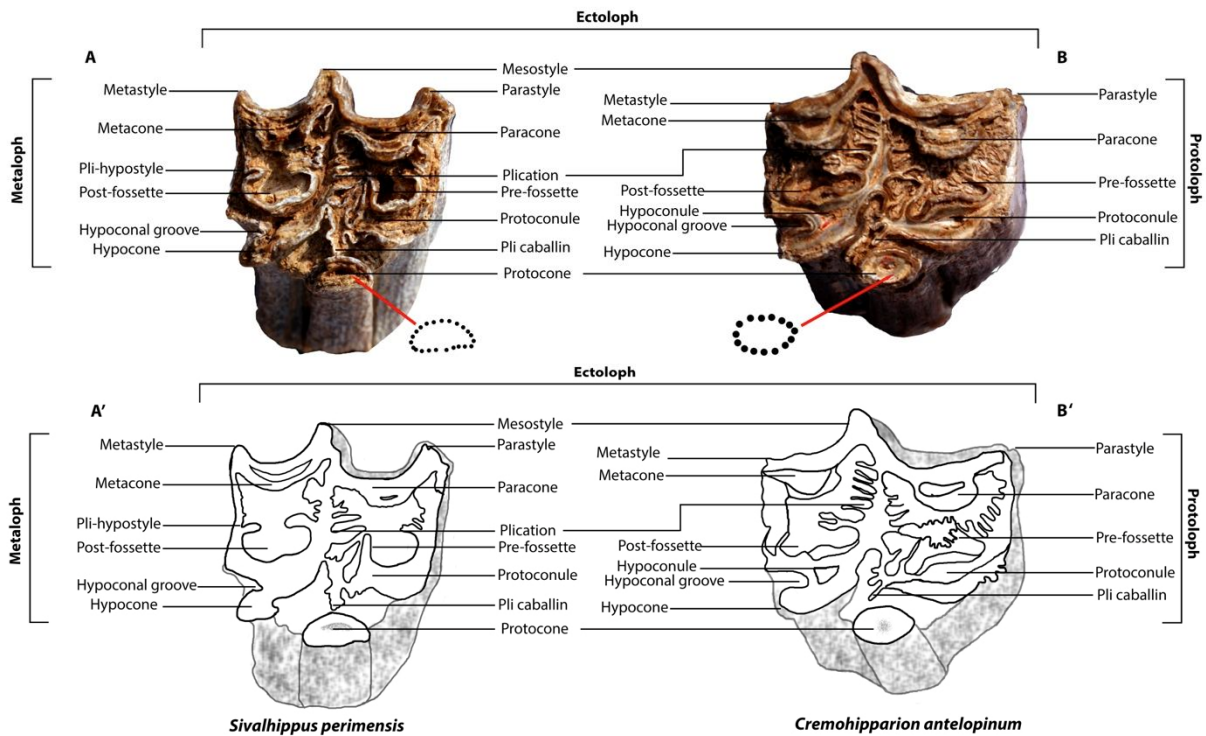


Fig. 1. The terminology used in the text (M3).

SYSTEMATIC PALAEOONTOLOGY

Superfamily Equoidea Hay, 1902

Family Equidae Gray, 1821

Subfamily Equinae Steinmann and Doderlein, 1890

Genus *CREMOHIPPARION* Qiu *et al.*, 1987

Cremohipparion antelopinum (Falconer and Cautley, 1849)

New Material

PUPC 13/79-right P3, PUPC 13/72-right P4, PUPC 13/75-right M3, PUPC 13/69-right p3, PUPC 13/67-left m1, PUPC 13/78-left m3, PUPC 13/80-left m3.

Description

Upper dentition

The premolars and molars are hypsodont and in early wear (Fig. 2A-C). All the cones are well developed and clearly visible. A thick layer of cement is present labio-lingually. The protocone is somewhat rounded and isolated. The hypocone is elongated and narrow. The paracone is almost equal

to the metacone in antero-posterior length. The posterior side is broader than the anterior one. All the styles are well developed and prominent. The parastyle and mesostyle are pillar-like in appearance. The metastyle is comparatively weak. The deeply incised hypoconal groove is present postero-lingually. The pre- and post-fossettes have simple plications. The premolar represents single plicaballin (Fig. 2A-B). The metaloph and ectoloph are crescent-shaped and clearly visible.

Lower dentition

The lower premolar and molars show a good stage of preservation, narrow crown and hypsodont (Fig. 2D-G). The cement is present labio-lingually. The hypoconid is forwardly directed and protoconid is backwardly directed. The hypoconid groove is present posteriorly. The stylids are well preserved. The metastylid is placed anteriorly. The mesostylid and entostylid is present lingually. The ectostylid is absent. Two prominent invaginations are present lingually: the metaflexid (anteriorly) and entoflexid

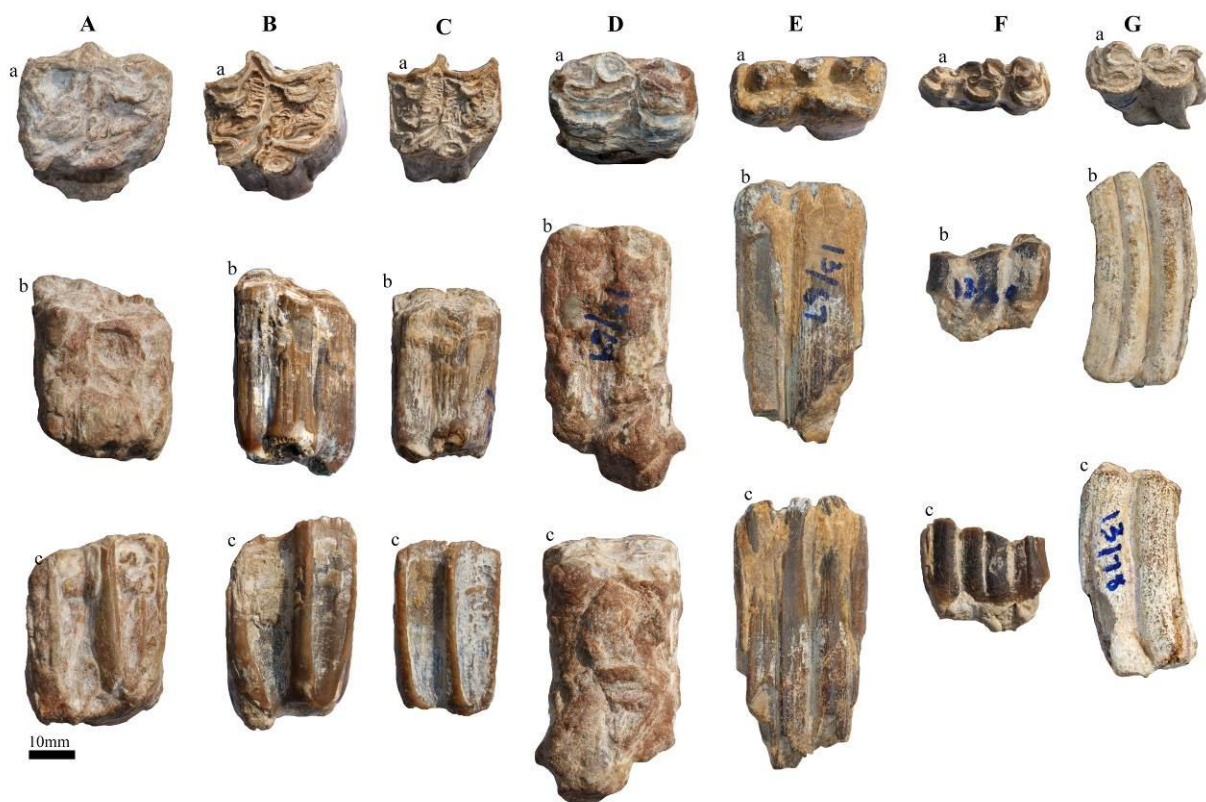


Fig. 2. *Cremohipparion antelopinum*: A, PUPC 13/79, rP3; B, PUPC 13/72, rP4; C, PUPC 13/75, rM3; D, PUPC 13/69, rp3; E, PUPC 13/67 lm1; F, PUPC 13/80, rm3; G, PUPC 13/78, partial lm3. Views: a, occlusal; b, lingual; c, labial. Scale bar 10 mm.

(posteriorly). The metaflexid is narrow in the middle and broad anteroposteriorly. The entoflexid is elongated, curved anteriorly while broad posteriorly. The hypoconulid is prominent in the third molar.

Remarks

The studied teeth are hypsodont and their styles are prominent. The protocone is somewhat rounded which are the characteristics that includes them in the species *Cremohipparion antelopinum*. *Cremohipparion* shows the following characters: simple plication frequency of pre-postfossettes, single pli caballin (versus bifid or complex), small size and somewhat rounded protocones (Wolf *et al.*, 2013). The protocone is rounded or oval-shaped in *Cremohipparion*. The enamel borders of the fossettes are thin in *Cremohipparion* (Bernor and Hussain, 1985; Wolf *et al.*, 2013). The specimens show basic features of the type specimen, like a

rounded protocone, a single pli caballin and shallowly incised hypoglyphs. In the lower molars and premolars, two prominent invaginations are present lingually: the metaflexid (anteriorly) and entoflexid (posteriorly). The metaflexid is narrow in the middle and broad antero-posteriorly. The metrical values are provided in Table I.

The name "*Hippotherium*" (=Hipparion) *antelopinum* was first introduced by Falconer and Cautley (1849). Subsequently, Gaudry (1862) and Lydekker (1882, 1883, 1884) used simply the name "*Hippotherium*" *antelopinum*. Shortly thereafter, Lydekker (1885) transferred this species from the genus "*Hippotherium*" to *Hipparion*. This convention has been followed by most subsequent authors (Lydekker, 1886; Matthew, 1929; Colbert, 1935; Gromova, 1952; Hussain, 1971; MacFadden and Woodburne, 1982). Hussain and Bernor (1984) and Bernor and Hussain (1985) recognized three



Fig. 3. *Sivalhippus perimensis*: A, PUPC 13/73, rM1; B, PUPC 13/66, rM2; C, PUPC 13/70, rM2; D, PUPC 13/71, rM3; E, PUPC 13/64, rM3; F, PUPC 13/65, rM3; G, PUPC 13/74, lp3; H, PUPC 13/76, lp4. Views: a, occlusal; b, lingual, c, labial. Scale bar 10 mm.

closely related species of *Cormohipparion* (*Sivalhippus*), i.e., *C. (S.) theobaldi*, *C. (S.) perimensis* and *C. (S.)* sp., and one species interpreted at the time as belonging to *Hipparion* s.s. (*?H. antelopinum*). In Bernor and Hussain (1985), it was likely referable to the genus *Cremohipparion*, which was established by Qiu *et al.* (1987). Recently, Bernor *et al.* (2010) suggested that the small taxon be given as *?H. antelopinum*. Wolf *et al.* (2013) established *Cremohipparion antelopinum* as a valid species in the Siwaliks.

Genus *Sivalhippus* (Lydekker, 1877a)
Sivalhippus perimensis (Pilgrim, 1910)

New material

PUPC 13/73-right M1, PUPC 13/70-right M2, PUPC 13/66-right M2, PUPC 13/71-right M3,

PUPC 13/64-right M3, PUPC 13/65-right M3, PUPC 13/74-left p3, PUPC 13/76-left p4.

Description

Upper dentition

The upper molars are broad-crowned and hypsodont with well-developed cusps (Fig. 3A-F). The protocone is elongated, oval in shape and isolated from rest of the crown. It is flattened lingually and circular labially. The hypocone is elongated with well-developed hypoconal groove. The paracone and metacone are similar in appearance. The hypostyle is pillar like and prominent. The enamel foldings are complex in the pre- and post-fossettes. The plicaballine is bifid. A thick layer of the cement is present labio-lingually. The upper third molar is triangular shape, having antero-convexity and postero-concavity.

Table I.- Comparative measurements (mm) of the cheek teeth of *Cremohipparion antelopinum* and *Sivalhippus perimense*. *Specimen pertaining this study. Referred data are taken from Hussain (1971), Bernor and Hussain (1985), Ghaffar *et al.* (2003) and Naseem *et al.* (2009).

Taxa	Number	Nature/Position	L	W	W/L
<i>Cremohipparion antelopinum</i>	PUPC 13/79*	rP3	29.4	24.1	0.82
	PUPC 13/72*	rP4	26.9	24.3	0.90
	PUPC 13/75*	rM3	23.7	20.8	0.88
	PUPC 13/69*	rp3	27.3	19.4	0.71
	PUPC 13/67*	lm1	28.6	12.6	0.44
	PUPC 13/78*	lm3	24.5	12.7	0.51
	PUPC 13/80*	rm3	26.6	10.8	0.41
	BMNH M 2647	P3	23.8	23.7	0.99
	BMNH M 16580a	P3	26.9	27.2	1.01
	BMNH M 16580b	P3	22.3	21.8	0.98
	BMNH M 2647	P4	23.2	23.0	0.99
	BMNH M16170	P4	23.6	22.7	0.96
	BMNH M2647	M3	18.8	14.4	0.77
	BMNH M16170	M3	20.1	17.6	0.88
	PC-GCUF 10/39	M3	20.0	16.0	0.80
	PC-GCUF 08/14	p3	6.9	12.8	1.86
	PC-GCUF 10/36	m1	26.0	14.0	0.54
	PC-GCUF 08/15	m1	25.5	13.4	0.53
	PUPC 96/16	m1	23.2	9.70	0.42
	BSM H15	m1	20.9	12.8	0.61
	PC-GCUF 10/42	m3	24.0	11.0	0.46
	PC-GCUF 10/43	m3	19.0	10.0	0.53
	PC-GCUF 10/45	m3	23.0	9.00	0.39
	<i>Sivalhippus perimense</i>	PUPC 13/73*	rM1	24.6	25.4
PUPC 13/70*		rM2	26.0	22.9	0.88
PUPC 13/66*		rM2	26.6	23.8	0.89
PUPC 13/71*		rM3	25.3	22.6	0.89
PUPC 13/64*		rM3	23.3	20.3	0.87
PUPC 13/65*		rM3	27.8	21.4	0.77
PUPC 13/74		IP3	26.3	16.3	0.62
GSI C349		M1	22.2	-	-
GSI C277		M1	26.9	24.5	0.91
GSI C 275		M1	21.3	26.5	1.24
AMNH 19761		M1	23.1	27.4	1.19
AMNH 19466		M1	26.7	26.8	0.97
AMNH 19676		M1	22.5	24.6	1.09
GSI C151		M1	24.9	26.7	1.07
GSI K 13/123		M1	20.0	24.2	1.21
GSI C349		M2	22.8	23.7	1.04
GSI C277		M2	26.2	21.4	0.82
GSI C275		M2	19.9	24.4	1.23
AMNH 19761		M2	23.7	24.8	1.05
AMNH 19466		M2	28.8	25.1	0.87
AMNH 19676		M2	22.1	22.1	1.00
GSI C151		M2	26.3	25.5	0.97
GSI K 13/123		M2	20.7	23.6	1.14
GSI C349		M3	24.4	19.6	0.80
GSI C275		M3	23.9	20.5	0.64
AMNH 19761		M3	23.3	21.0	0.90
AMNH 19466		M3	23.8	20.5	0.86
AMNH 19676		M3	21.1	28.8	1.36
GSI K 13/123		M3	20.8	21.6	1.04
PUPC 13/76		lp4	24.5	12.7	0.52

Lower dentition

The lower dental elements comprise the third and fourth premolars (Fig. 3G-H). The occlusal surface is narrow. The linguflexid is deep and U-shaped. The ectoflexid is deep terminating to the metaconid-metastylid valley. The preflexid and postflexid is clearly visible having simple margins. The styles are well preserved and prominent. The protostylid and parastylid are pillar-like in appearance. The specimens are conformable (Table I) to the species *Sivalhippus perimensis*.

Remarks

The holotype skull GSI C349 was originally reported by Lydekker (1883) and named *Hippotherium "antelopinum"*. Lydekker (1886) renamed the same specimen to *Hipparion punjabiense*. Pilgrim (1910) named the species "*Hipparion*" *perimensis* by designating the same skull as holotype (e.g., Pilgrim, 1913; Matthew, 1929; Colbert, 1935; Gromova, 1952; Hussain, 1971; Skinner and MacFadden, 1977; MacFadden and Woodburne, 1982). Bernor and Hussain (1985) mentioned *Hipparion* (*Sivalhippus* complex) *perimensis* for the same specimens. Recently, Wolf *et al.* (2013) raised the *Sivalhippus* complex to generic rank and recognized four distinct species: *Sivalhippus nagriensis*, *S. theobaldi*, *S. perimensis* and *Cremohipparion antelopinum*. They noted that *Sivalhippus perimensis* was a more derived endemic species occurred between circa 8.5 and 7.8 Ma, co-occurring with a distinct immigrant population of hipparions of small body size, *Cremohipparion antelopinum*.

DISCUSSION

The perissodactyl fauna of the Dhok Pathan comprises rhinos, chalicotheres and hipparionines (Heissig, 1972; Iqbal *et al.*, 2009; Khan *et al.*, 2009, 2010). Hipparionines are abundantly found in the Middle Siwaliks and considered to be a biostratigraphic indicator of Late Miocene to Early Pliocene deposits of Pakistan (Barry *et al.*, 2002; Badgley *et al.*, 2005; Naseem *et al.*, 2009; Wolf *et al.*, 2013; Khan *et al.*, 2014).

The hipparionine horses contribute heavily to the classic increase in hypsodonty among ungulates.

Somewhat hipparionine horses, common find in many localities, appear as the first wave of the increase in hypsodonty followed by other ungulates later in the Neogene. This is evidently a result of their having evolved hypsodonty in North America before their dispersal to the Old World at the beginning of the Late Miocene. Hypsodonty is recognized as an ecological proxy to interpret habitat and feeding preferences in herbivorous mammals for unraveling their ecological reconstructions (Janis *et al.*, 2002; Jernvall and Fortelius, 2002; Fortelius *et al.*, 2003). The dietary inferences in ungulate remains can provide both paleoecological information of individual species, and mammalian paleocommunities in terrestrial ecosystem (Kaiser *et al.*, 2000). The broad geochronologic ranges with dietary and habitat preferences of hipparionine can provide significant biostratigraphic and paleoecological information (Pilbeam *et al.*, 1997; Barry *et al.*, 2002).

The coexistence of the Siwalik hipparionine with mammalian faunal elements of Late Miocene suggested a whole spectrum of habitats ranging from pronounced woodlands to extreme steppes. The limb metapodials of hipparionine reflect typical anatomical changes compatible with the transitional life mainly from forest to steppe (Khan *et al.*, 2011; Wolf *et al.*, 2013). *Sivalhippus* preferred more open and drier mosaics of the vegetation as revealed by the most enriched carbon and oxygen isotopic values of its specimens at latest Miocene (Badgley *et al.*, 2005; Nelson, 2005; Khan *et al.*, 2011; Wolf *et al.*, 2013).

CONCLUSIONS

Cremohipparion antelopinum and *Sivalhippus perimensis* are recorded from the Late Miocene of the Dhok Pathan type locality, Chakwal district, Northern Pakistan. The sediments of the Dhok Pathan type locality date Late Miocene to Early Pliocene in age. The Siwalik hipparionine preferred more open and drier mosaics of woodlands. The presence of the medium-sized antilopes alongside *Sivalhippus* in the Dhok Pathan type locality of the Middle Siwaliks indicates that wooded-grassy savannas and grasslands were

present during the Late Miocene – Early Pliocene.

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