

Some New Remains of Hipparionine (Equidae: Mammalia) from Dhok Pathan Upper Miocene, Northern Pakistan

Muhammad Akbar Khan^{1*}, Sadaqat Ali², Javed Iqbal² and Muhammad Akhtar¹

¹Palaeontology laboratory, Zoology Department, Quaid-e-Azam Campus, University of the Punjab, Lahore

²Department of Wildlife & Fisheries, GC University, Faisalabad

Abstract.— New hipparionine remains from the Dhok Pathan type locality of the Chakwal district, Punjab, Pakistan, are described and discussed. The discovered material is attributed to two species *Sivalhippus* cf. *theobaldi* and *Cremohipparion* cf. *antelopinum*; each is represented by seven specimens. The recovered fossils contribute additional knowledge on the dental features of the Dhok Pathan's hipparionine horses.

Keywords: Vertebrate fossils, *Cremohipparion*, *Hipparion*, *Sivalhippus*, Siwaliks.

INTRODUCTION

The systematic study on Siwalik hipparionines has been carrying out for more than 150 years. The first systematic study of the Siwalik hipparionines was made by Falconer and Cautley (1849). Subsequently, Gaudry (1862), Lydekker (1877a,b, 1882, 1883, 1884, 1885, 1886), Pilgrim (1910, 1913), Matthew (1929), Colbert (1935) and Gromova (1952) reviewed the Siwalik hipparionines, based on the traditional systematic characterizations: size, cheek tooth ornamentation, protocone shape, and metapodial proportions. A comprehensive revision was made by Hussain (1971), and noted that a single migration of a *Hipparion* primitive species, *Hipparion nagriensis* during Lower Nagri time led to the local diversity of two *Hipparion* taxa in the Middle Siwalik horizons: *Hipparion antelopinum*, a small form with slender elongate third metapodials and more hypsodont teeth, and *Hipparion theobaldi*, a large form with more massive third metapodials and more hypsodont teeth than *Hipparion nagriensis*.

The detailed systematic investigations of the Siwalik hipparionines have been made by Skinner and MacFadden (1977), MacFadden and Bakr (1979), and MacFadden and Woodburne (1982), based primarily on facial and dental characteristics. Skinner and MacFadden (1977) referred *Hipparion theobaldi* and *Hipparion antelopinum* to

Cormohipparion. Afterwards, MacFadden and Bakr (1979) identified three groups *Cormohipparion* (*C. theobaldi*), a small *Hipparion*-complex incertae sedis, and *Hipparion* sensu strictu. MacFadden and Woodburne (1982) revised the Siwalik hipparionines and erected four species: *Hipparion antelopinum*, *Hipparion feddeni*, *Cormohipparion theobaldi*, *Cormohipparion* cf. *nagriensis* and *Hipparion* sp. In 1985, Bernor and Hussain ascribed two supraspecific groups of the Siwalik hipparionines: the *Cormohipparion* (*Sivalhippus*) group (which includes three species: *C. (S.) perimensis*, *C. (S.) theobaldi*, *C. (S.)* species) and ?*Hipparion* s.s. (includes one species ?*H. antelopinum*). The validity of *H. nagriensis* (Hussain, 1971) was not resolved by Bernor and Hussain (1985: 54) owing to insufficient material and incomplete information.

The most recent systematic of Siwalik hipparionines was made by Wolf *et al.* (2013) and recognized four distinct species: *Sivalhippus nagriensis*, *S. theobaldi*, *S. perimensis* and *Cremohipparion antelopinum*. They synonymized *H. nagriensis* (*Cormohipparion* cf. *nagriensis* of MacFadden and Woodburne, 1982) with a more derived taxon *Sivalhippus nagriensis* and noted that the species was dominated between ca. 10.7 and 9.3 Ma. *Sivalhippus theobaldi*, identified as a large species with massive cheek teeth, was present at ca. 9.3 Ma. The more derived endemic species

* Corresponding author: akbaar111@yahoo.ca
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Abbreviations: PC-GCUF, Palaeontological Collection of Government College University Faisalabad, Punjab, Pakistan; PUPC, Punjab University Palaeontological Collection, Lahore, Punjab, Pakistan; Ma, Million years ago; ca, Circa.

Sivalhippus perimensis occurred between ca. 8.5 and 7.8 Ma alongside occasional *Sivalhippus theobaldi*, co-occurring with a distinct immigrant population of hipparions with small body size, *Cremohipparion antelopinum*. Nevertheless, this systematic is now formally founded, and following Wolf *et al.* (2013), we shall now continue to use these two supraspecific groups as valid taxa in the Siwaliks. We describe herein new hipparionine remains from the Dhok Pathan type locality of the Dhok Pathan Formation in northern Pakistan.

MATERIALS AND METHODS

Geography and geology

The studied material has been recovered from the type locality of the Dhok Pathan Formation. The Dhok Pathan village is situated in the district Chakwal, in northern Pakistan comprising the outcrops of Late Miocene – Early Pliocene (10.1-3.4 Ma) in age deposits (Barry *et al.*, 2002; Khan *et al.*, 2010). The sediments of the Dhok Pathan Formation in the type locality have a thickness of 950-1200 m, exhibiting an excellent development of cyclic deposition of shale and sandstones. Almost nine fluvial cycles have been recorded by Pilbeam *et al.* (1977) at the Dhok Pathan stratotype.

The much younger, horizontally bedded Potwar silts are unconformably overlying the Dhok Pathan Formation. The Dhok Pathan Formation sediments were deposited in typical semi and sub-tropical climatic conditions, containing plant fragments and vanadium rich minerals. In some areas the Formation contains a considerable amount of humic acid and pyrite, formed during diagenesis and these important reductants provided reducing conditions for uranium deposition. The Dhok Pathan Formation is composed of sandstones with alternate clay and a minor layer of conglomerates in lower part and more conglomerates with sandstone and clay in upper part. The clays are orange-brown in colour (Pilbeam *et al.*, 1977; Barry *et al.*, 2002). The geology and geography of the Dhok Pathan type locality is provided in Khan *et al.* (2010).

The various field trips were carried out for the collection of the hipparionine specimens from the Dhok Pathan type locality. Emphasis was placed

on collecting fossils of large vertebrates. Fossils were collected thoroughly from the fossilized sites of the type locality. Those fossils which are identifiable, selected from the gross collection, numbered and registered for the taxonomic study. The fossils were thoroughly washed and cleaned in the laboratory with the help of fine needles and brushes and prepared for the study. Broken parts of the fossils were assembled with some kinds of gums (resins) such as elfy, elite, fixin, araldite and magic stone.

The specimens catalogue number consist of a yearly catalogue number and serially catalogue number, so numbers on the specimens represent the collection year and the serial number of that year (e.g. 10/38). Upper case letters stand for upper dentition and lower case letters for lower dentition. The measurements are taken on the occlusal surface of the teeth, including the cement and separately from the teeth belonging to different stages of wear.

Usually, molars are smaller than premolars, especially in their width. The molars are usually wider anteriorly than posteriorly, it is reverse on premolars. The occlusal surfaces are more or less at right angles with the crown in premolars; in molars especially in M2, the crown is distally incurved backwards. In premolars, the hypoconid is usually wide and it is short in molars, it tends to be thinner, elongated, and to be separated from the entoconid by a sort of neck. Usually, the ectoflexid is relatively shallow on premolars and deep in molars (Eisenmann *et al.*, 1988).

SYSTEMATIC PALAEOLOGY

Order Perissodactyla Owen, 1848

Suborder Hippomorpha Wood, 1937

Superfamily Equoidea Hay, 1902

Family Equidae Gray, 1821

Subfamily Equinae Stemmann and Dodeleirin, 1890

Genus *SIVALHIPPIUS* (Lydekker 1877a)

Sivalhippus cf. theobaldi (Lydekker, 1882)

Synonymy

Hippotherium theobaldi Lydekker, 1877b;
Hippotherium theobaldi Lydekker, 1882;
Hippotherium theobaldi Lydekker, 1884; *Hipparion theobaldi* Lydekker, 1885; *Hipparion theobaldi*

Lydekker, 1886; *Hipparion theobaldi* (in part), Pilgrim, 1913; *Hipparion theobaldi* (in part), Matthew, 1929; *Hipparion primigenium* (in part), Forsten, 1968; *Hipparion theobaldi* (in part) Hussain, 1971; *Cormohipparion theobaldi* (in part) Skinner, and MacFadden, 1977; *Cormohipparion theobaldi* (in part) MacFadden and Woodburne, 1982; *Cormohipparion (Sivalhippus) theobaldi* (Lydekker, 1877a), new combination, Bernor and Hussain, 1985.

Holotype

GSI C349, adult skull with left P2-M3.

Type locality

Nagri Zone, Perim Island, India.

Referred material

PC-GCUF 10/34, left upper first and second premolars (P1-2); PC-GCUF 10/41, an isolated left upper second premolar (P2); PUPC 07/02, an isolated left upper second premolar (P2); PC-GCUF 07/29, an isolated left upper first molar (M1); PC-GCUF 10/35, an isolated right upper second molar (M2); PC-GCUF 10/38, an isolated right upper second molar (M2); PC-GCUF 10/44, an isolated right lower third molar (m3).

Description

The premolars are well preserved (Fig. 1A-C). The cement is present lingually and the enamel is moderately thick. The P1 is unworn; it is domed shaped, with a relatively small size (rudimentary), joining the anterostyle of the P2 by a thin layer of cement (Fig. 1A). The second upper premolars are almost triangular with well-developed elongated anterostyles. The mesostyle is pillar-like and similar to the parastyle. It is broad at the base and narrow at the apex. The metastyle is moderately developed and straight. The protocone is an isolated compressed pillar and elongated in shape. The paracone is greater anteroposteriorly and similar to the metacone. The hypocone is narrow and elongated, covered with a thick layer of cement anteriorly. The pre-fossette and post-fossette are plicated with minimum enamel folding at the posterior border of the pre-fossette and at the anterior border of the post-fossette. The protoloph

and the metaloph are crescent shaped. The bifid pli caballin touches the inner margin of the protocone. The hypocone is not separated anteriorly from the metaloph, while posteriorly it is separated from the metaloph by a moderately-developed hypoconal groove (Fig. 1A-C).

The upper molars are hypsodont with well preserved major cusps (Fig. 1D, E). The protocone is a triangular shaped isolated pillar (flattened lingually). The paracone extends posteriorly and reflects an ovate shape. The hypocone is narrow and elongated with well-developed hypoconal groove. The parastyle, mesostyle and metastyle are well preserved. The mesostyle is compressed. The pli caballins are complicated. The pre- and post-fossettes are plicated with thickly banded enamel (Fig. 1D, E). The third molar is characterized by the presence of a hypoconulid posteriorly (Fig. 1F). It is narrow at the apex and broad at the base. The hypoconulid is lower in height than the other conids but very similar to the others.

Comparison

First premolar is rarely reported from the Siwaliks. The general appearances of the studied specimens with loph/lophids and enamel plications associate them to family Equidae. The isolated protocone excludes the specimens from the genus *Equus* and favour their inclusion to the group hipparionine. The hipparionine horses are with an isolated protocone on maxillary premolar and molar teeth and, as far as known, tridactyl feet, including genera: *Cormohipparion*, *Neohipparion*, *Nannippus*, *Pseudhipparion*, *Hipparion* (North American genus), *Hippotherium*, *Cremohipparion*, *Hipparion*, *Sivalhippus*, *Eurygnathohippus* (= senior synonym of *Stylohipparion*), *Proboscidipparion*, *Plesiohipparion* (Wolf *et al.*, 2013).

A significant size difference has been noted by many authors in dental and metapodial dimensions between the two supraspecific hipparionine groups of the Siwaliks: *Sivalhippus* and *Cremohipparion* (e.g. Bernor and Hussain, 1985; Bernor *et al.*, 1996; Khan *et al.*, 2010, 2011; Wolf *et al.*, 2013). The large size of the teeth with high frequency of plications in pre-postfossettes and bifid (in some teeth trifid) pli caballins are the distinct feature of the genus *Sivalhippus*. *Cremohipparion*



Fig. 1. *Sivalhippus* cf. *theobaldi*: A. PC-GCUF 10/34, left P1-2. B. PC-GCUF 10/41, left P2. C. PUPC 07/02, left P2. D. PC-GCUF 07/29, left M1. E. PC-GCUF 10/35, right M2. F. PC-GCUF 10/44, right m3. a = occlusal view, b = lingual view, c = labial view. Scale bar 10 mm.

differs from *Sivalhippus* in having 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* but it is compressed, strongly flattened lingually in *Sivalhippus*. The enamel borders of the fossettes are relatively thick in *Sivalhippus* and thin in *Cremohipparion* (Bernor and Hussain, 1985; Wolf *et al.*, 2013).

The morphometric features of the studied sample show all the typical features of the genus *Sivalhippus* and the species *Sivalhippus theobaldi* such as large sized molars, complex fossette ornamentation, double pli caballins, deep incisure of hypoglyphs and compressed protocones (lingually

flattened, labially rounded) (Fig. 1, Table I). As the quantity of the collected and studied sample is considered insufficient, only its assignment to *Sivalhippus* cf. *theobaldi* is plausible. The measured dimensions of the studied material are slightly different from previously studied specimens (Table I). This variation is within the specific level and can be considered as intraspecific morphometric variation.

Genus *CREMOHIPPARION* Qui, Weilong & Zhiui, 1988

Cremohipparion cf. *antelopinum*

Synonymy

Hippotherium antelopinum Falconer and Cautley,

Table I.- Comparative measurements (in mm) of the cheek teeth of the hipparionines from the Siwaliks.

Taxa	Number	Nature/ Position	Length	Width
<i>S. cf. theobaldi</i>	PC-GCUF 10/34*	P1	11.5	7.00
		P2	40.0	22.0
	PC-GCUF 10/41*	P2	35.0	21.0
	PC-GCUF 07/02*	P2	37.0	22.0
	PC-GCUF 07/29*	M1	29.0	20.0
	PC-GCUF 10/35*	M2	30.0	24.0
	PC-GCUF 10/38*	M2	24.0	24.0
	PC-GCUF 10/44*	m3	31.0	12.0
	AMNH 19466	M3	24.0	22.0
	AMNH 19857	M3	25.0	23.0
	PC-GCUF 09/39	P2	32.0	25.0
	PUPC 83/284	P2	39.5	21.5
	AMNH 19857	P2	32.0	26.5
	PUPC 83/284	P2	39.5	21.5
	GSI C153	P2	38.5	26.0
	PUPC 83/498	P2	40.0	22.0
	AMNH 19466	P2	38.5	26.0
	AMNH 19466	M1	26.0	26.0
	AMNH 19857	M1	25.0	21.0
	PC-GCUF 09/37	M1	26.0	22.0
	PUPC 00/99	M1	26.0	23.0
	AMNH 19723	M1	23.0	23.0
	AMNH 19752	M1	23.0	23.5
	AMNH 19676	M1	24.0	23.0
	AMNH 19492	M1	22.0	20.0
	PC-GCUF 09/38	M2	25.4	22.3
	PC-GCUF 09/40	M2	24.0	24.0
	PC-GCUF 09/41	M2	23.0	22.0
	PUPC 00/99	M2	26.0	24.0
	AMNH 19723	M2	22.5	22.5
	AMNH 19752	M2	23.0	22.0
	AMNH 19676	M2	22.0	21.0
AMNH 19492	M2	21.5	20.0	
<i>C. cf. antelopinum</i>	PC-GCUF 10/39*	M3	20.0	16.0
	PC-GCUF 10/36*	m1	26.0	14.0
	PC-GCUF 10/42*	m3	24.0	11.0
	PC-GCUF 1043*	m3	19.0	10.0
	PC-GCUF 10/45*	m3	23.0	9.00
	PC-GCUF 08/15	m1	25.5	13.4
	PUPC 96/16	m1	23.2	9.70
	BSM H15	m1	20.9	12.8
	PC-GCUF 08/11	m2	23.2	13.6
	PC-GCUF 08/12	m2	26.3	13.4

*The studied specimens. Referred material is taken from Colbert (1935), Hussain (1971), Bernor and Hussain (1985), Ghaffar (2005), Iqbal *et al.* (2009), Naseem *et al.* (2009), and Khan *et al.* (2011).

1849; *Hippotherium antelopinum* Gaudry, 1862; *Hippotherium antilopinum* Lydekker, 1882; *Hipparion antilopinum* (in part) Lydekker, 1885; *Hipparion antilopinum* (in part) Lydekker, 1886; *Hipparion antelopinum* (in part) Matthew, 1929;

Hipparion antelopinum (in part) Colbert, 1935; *Hipparion antelopinum* (in part) Hussain, 1971; *Hipparion antelopinum* (in part) MacFadden and Woodburne, 1982; ?*Hipparion antelopium* Bernor and Hussain, 1985.

Holotype

BMNH M2647, sub-adult right maxilla fragment with P2-M3.

Type locality

Middle Siwaliks, Dhok Pathan district, Punjab province, northern Pakistan.

Referred material

PC-GCUF 10/40, an isolated right upper partial molar (M?); PC-GCUF 10/39, right M3; PC-GCUF 10/37, an isolated right lower fourth premolar (p4); PC-GCUF 10/36, an isolated right lower first molar (m1); PC-GCUF 10/42, an isolated right lower third molar (m3); PC-GCUF 10/43, an isolated left lower third molar (m3); PC-GCUF 10/45, an isolated right lower third molar (m3).

Description

The one upper molar is partially preserved. The third upper molar shows simple occlusal morphology (Fig. 2A). The plication frequency of the enamel in the pre-, postfossettes is low. The protocone is somewhat rounded and isolated. There is a single pli caballin. The protocone and hypocone are broader than the paracone and the metacone. The styles are strong. The occlusal characteristics of the molars: plio-protoloph, plio-fossettes, plio-hypostyle and hypoconal groove, are clearly visible.

In the p4, the protoconid and the hypoconid are angular; the metaconid is triangular and the entoconid is sub-ovate. The metaflexid and the entoflexid are somewhat triangular (Fig. 2B). The anterior vestibule horn of the post-fossette is much more developed in the vestibular direction than the posterior vestibule horn of the pre-fossette.

The lower molars have a narrow crowned, are hypsodont and bear the metaflexid and entoflexid (Fig. 2C). The metaflexid presents an anterior invagination between the protoconid and the metaconid. Similarly, the entoflexid presents a posterior invagination between the hypoconid, the



Fig. 2. *Cremohipparion* cf. *antilopinum*: **A.** PC-GCUF 10/39, right M3. **B.** PC-GCUF 10/37, right p4. **C.** PC-GCUF 10/36, right m1. = occlusal view, b = lingual view, c = labial view. Scale bar 10 mm.

entoconid and the mesostylid. Both the metaflexid and the entoflexid have complicated enamel foldings with extremities. The metaflexid is broad in the middle and narrow anteroposteriorly. The entoflexid is elongated. The lingual conids are slightly vertically higher than that of the labial ones.

Comparison

The described material has simple enamel plications with round to ovate isolated protocone and shows all the basic features of *Cremohipparion antelopinum* (Falconer and Cautley, 1849; Colbert, 1935; Bernor and Hussain, 1985; Iqbal *et al.*, 2009; Wolf *et al.*, 2013). The size and occlusal pattern of *Cremohipparion antelopinum* differentiate it from *Sivalhippus* in having small size, simple enamel plications, single pli caballin, hypoglyph moderately incised and round to ovate protocone. The described material shows all the morphometric characters of *Cremohipparion antelopinum* (Fig. 2, Table I) and owing to insufficient sample *Cremohipparion cf. antelopinum* is assigned to the studied material.

DISCUSSION AND CONCLUSION

The Siwalik hipparionine species are chiefly based on teeth and the difference is not completely clear among *Sivalhippus theobaldi*, *S. perimensis*, *S. nagriensis* and the other geologically younger species (Wolf *et al.*, 2013). *Sivalhippus* differs in facial, dental and maybe postcranial features to *Cremohipparion* (Bernor and Hussain, 1985; Iqbal *et al.*, 2009; Naseem *et al.*, 2009; Khan *et al.*, 2011; Wolf *et al.*, 2013). In evolutionary perspective, the *Sivalhippus* group is a conservative group and compares closely with *Hippotherium primigenium* and other primitive horses in having complex cheek teeth, fossette ornamentation, double or complex pli caballins, deeply incised hypoglyph and elongate P2 anterostyle. *Cremohipparion* closely resembles in their metapodial proportions *H. crassum* (Lydekker, 1883, 1884; Bernor *et al.*, 1996). The Upper Miocene hipparionine species described from Eurasia and Africa have common dental characters and can be considered 'primitive' in relation to the European *H. crassum* group (Colbert, 1935; Ghaffar, 2005; Bernor *et al.*, 1996).

Two species of the hipparionine group have been identified from the Dhok Pathan type locality, northern Pakistan: *Sivalhippus cf. theobaldi* and *Cremohipparion cf. antelopinum*. The associated fauna of the type locality compares well to the hipparionine group (Colbert, 1935; Matthew, 1929; Pilgrim, 1937, 1939; Khan *et al.*, 2010). The large mammals like *Pachyportax*, *Selenoportax*, and *Bramatherium* are also recorded from the Dhok Pathan faunas (Matthew, 1929, Colbert, 1935; Khan *et al.*, 2010). In accord with the associated fauna of the type locality, particularly with the bovid taxa *Pachyportax*, *Selenoportax* and *Gazella* the presence of hipparionine horses may be representative for the presence of drier and more open habitats. These taxa inhabited relatively more arid and more open environments. The hipparionine fauna suggests an evergreen woodland environment was present, similar to today's mixed monsoon forest and grassland glades of north central India.

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