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A NEW COLLECTION OF HIPPARIONINE FROM THE TYPE LOCALITY OF THE DHOK PATHAN FORMATION OF THE MIDDLE SIWALIKS

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ABSTRACT

The new discovered material found from the Dhok Pathan type locality identifies two species of Hipparionine, *Sivalhippus* cf. *theobaldi* and *Hipparion* sp. The described material consists of the isolated upper cheek teeth and reflects all morphological features of *Sivalhippus* cf. *theobaldi* and *Hipparion* sp. *Sivalhippus* cf. *theobaldi* comprises two well preserved specimens and *Hipparion* sp. comprises four well preserved specimens. *Sivalhippus* cf. *theobaldi* is a large species with less complicated enamel plications whereas *Hipparion* sp. is moderate in size with more complicated enamel plications.

Key words: *Hipparion*, Middle Siwaliks, Mammals, Dhok Pathan Formation.

INTRODUCTION

In the Siwaliks, *Hipparion* first appeared by a single migration, recorded in lithologic boundary of the Nagri Formation (Pilbeam *et al*., 1997). *Hipparion* sp. was found abundantly in the Middle Siwaliks and considered to be as one of the faunal members of the Siwalik Late Miocene sediments (Hussain, 1971; Naseem *et al*., 2009). The systematics of the recovered *Hipparion* material from the Dhok Pathan type locality is the central focus of this paper.

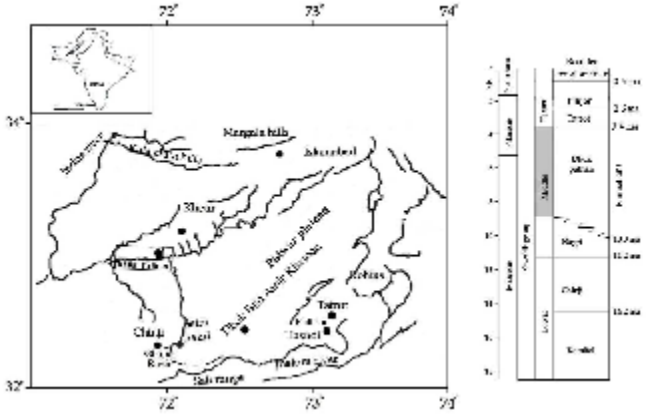

Fig. 1. Map of the Potwar Plateau showing Dhok Pathan type locality encircled from where the fossils were collected. A generalized stratigraphic section of the major Siwalik formations showing succession and ages is also indicated.

The studied material is recovered from the type locality of the Dhok Pathan Formation. The village Dhok Pathan locality is situated in district Chakwal and is of the late Miocene to Pliocene in age (Fig. 1). The Dhok Pathan Formation is composed of sand stones with alternate clay and minor layers of conglomerate in lower part and more conglomerates with sandstone and clay in upper part. The clays are orange brown in colour (Barry *et al*., 2002).

MATERIALS AND METHODS

The various field trips were carried out for the collection of the *Hipparion* specimens in the Dhok Pathan type locality. Emphasis was placed on collecting the fossils of the large vertebrates. Those fossils which were identifiable, selected from the gross collection, catalogued and preserved for the taxonomic study. Those fossils which were not in well preserved condition, thoroughly washed and cleaned in the laboratory with the help of the fine needles and brushes and, prepared for the study. Specimens catalogued number consist of series i.e., yearly catalogue number and serial catalogue number, so figure on the specimens represents the collection year and the serial number of that year (e.g. PC-GCUF 09/38, PC-GCUF is an institutional abbreviation). Upper case letters stand for upper dentition and lower case letters for lower dentition. The material is housed in the Palaeontology laboratory of the Zoology Department of GC University, Faisalabad. Terminology follows Forsten (2002) and Naseem *et al*. (2009). *Hipparion* has medium to large size and moderately high tooth crowns with the enamel richly plicated and crenulated. In the upper cheek teeth the protocones and hypocones are short relative to tooth occlusal length, and the hypoconal grooves are simple and widely open. In the

lower cheek teeth, the cingular stylids are weakly developed.

SYSTEMATIC PALAEONTOLOGY

Family EQUIDAE Gray, 1821
Subfamily EQUINAE Gray, 1821
Genus *HIPPARION* De Christol, 1832

Sivalhippus cf. *theobaldi* (Lydekker) 1882

Holotype: GSI C153, left maxilla with DP2-4.

Horizon: Middle Siwaliks.

Diagnosis: A large hipparion with tridactyl feet and deep preorbital facial fossa separated from the orbit by a relatively wide preorbital bar, fossa deeply pocketed posteriorly, medially deep and with a well defined continues peripheral border including the anterior rum, cheek teeth complexly ornamented with thickly banded fossette plications and bifid to trifid plicaballins, protocones distinctly flattened lingually and rounded labially, hypoglyphs deeply incised, P2 anterostyle elongate (Colbert, 1935; Ghaffar, 2005).

Referred Material: PC-GCUF 09/39, isolated left upper second premolar (P2). PC-GCUF 09/36, isolated left upper second molar (M2).

Description: Second premolar PC-GCUF 09/39 is almost triangular with characteristically well developed anterostyle. It is strongly elongated and pillar like (Fig. 2(1)). All the major cusps are well developed and preserved. The protocone is an isolated compressed pillar and elongated in shape. It is covered by a moderately thick layer of cement. The hypoconal groove is also well developed and placed posteriorly. The styles are well preserved, strongly developed and prominent. The mesostyle is pillar like structure and is similar to the parastyle in general appearance. Both the styles are broad at the base and narrow at the apex. The metastyle is moderately developed and straight in shape. The hypostyle is weak and not prominent like others. The protoloph, the metaloph, and the ectoloph are distinguished. The crown is highly plicated (Fig. 2(1c)).

The molar PC-GCUF 09/36 is hypsodont, in an early stage of wear (Table 1) and well preserved. The protocone is isolated, well preserved, and compressed (Fig. 2(2c)). The hypoconal groove is prominent. All the styles are preserved in good condition on buccal side and strongly developed. The pararstyle and the mesostyle are more developed than that of the metastyle (Fig. 2(2a)). The metacone is broad than the paracone. The protoloph, the ectoloph and the metaloph are well developed and prominent. The fossettes are also clear. The pre-fossettes and the post-fossettes are plicated with enamel folding (Fig. 2(2c)). A thick layer of cement is present all over the crown. The comparative measurements are provided in table 1.

Table 1. The comparative measurements (mm) of *Sivalhippus* cf. *theobaldi*. Referred material is taken from Ghaffar (2005) and Colbert (1935). * The referred specimens.

Serial Number	Speci-mens	Width	Length	Height
PC-GCUF 09/39	P2	25	32.2	47
*PUPC 83/284	P2	21.5	39.5	22
*PUPC 83/498	P2	22	40	20
*GSI C 153	P2	26	38.5	-
*AMNH 19857	P2	26.5	32.0	-
*AMNH19466	P2	26.0	38.5	-
PC-GCUF 09/36	M2	25.5	25	51
*AMNH19857	M2	25.0	21.0	-
*AMNH 19466	M2	26.0	26.5	-

Discussion: The general appearance of the studied specimens and strong pillar like isolated protocone exclude the specimens from the genus *Equus* and favor their inclusion in the genus *Sivalhippus*. Most authors have noted the significant size differences in dental and metapodial dimensions between the type collection of *Sivalhippus* and *Hipparion* (Fig. 3a-c). *Sivalhippus theobaldi* are long in size, have less complicated plications and the enamel foldings are visible. *Sivalhippus theobaldi* differs from *Hipparion* sp. on the basis of the following distinctions: Greater size of molars, and they are more oblong and less square shape in *Sivalhippus theobaldi*; the protocone compressed, as compared to rounded oval shape protocone in *Hipparion* sp.; hypocone extending back to the posterior border of the molar crown in *Sivalhippus theobaldi*; hypocone united to the posterior crescent in DP2 in *Sivalhippus theobaldi;* enamel borders of fossettes relatively simple in *Sivalhippus theobaldi* and complicated in *Hipparion* sp. (Lydekker, 1882; Colbert, 1935; Bernor *et al*., 1996).

The morphology of the studied specimens reveals all the features of species *Sivalhippus theobaldi* as described by Lydekker (1882), Colbert (1935) and Ghaffar (2005). This species is characterized by the isolated, compressed and pillar like protocone, the molar size is large (Fig. 3a-c). The enamel bordering of the fossettes are relatively simple. As indicated by measurements, the specimens are extremely hypsodont and show less complicated plications (Table 1). The studied specimens show the same basic features of the species such as an anterostyle in premolars and isolated protocone in cheek teeth, simple enamel bordering of fossettes with large size. According to Colbert (1935), it is heavy and large species (Fig. 3a-c). The sample is insufficient and can be assigned to *Sivalhippus* cf. *theobaldi* the measurements of the described material are slightly different from the type specimens given by Ghaffar (2005) and Colbert (1935).

***Hipparion* sp.**

***Holotype*:** BMNH M2647 sub-adult right maxilla with P2-M3.

Horizon: Middle Siwaliks.

Diagnosis: An average sized hipparionine, characterized by small and very hypsodont teeth, oval protocones complicated by enamel plications of the upper molars, facial fossa probably small with small dorsoventral height, compared with distance of facial maxillary crest from the ventral limit of the fosssa, plication usually single, hypoglyph moderately deeply incised, short snout and slender metapodials (Colbert, 1935; Ghaffar, 2005).

Referred Material: PC-GCUF 09/37, isolated left upper first molar (M1). PC-GCUF 09/38, isolated right upper second molar (M2). PC-GCUF 09/40, isolated right upper second molar (M2). PC-GCUF 09/41, isolated right upper second molar (M2).

Description: A thick layer of cement is present on the lingual side of the tooth in PC-GCUF 09/37 (Fig. 2(3b)). A moderately thick layer of enamel is present all over the crown (Fig. 2(3c)). All the cusps are well developed. The protocone is isolated from the rest of the crown and is pillar like elongated and sub ovate in shape. The hypoconal groove is not well preserved and damaged. The hypocone is broad and elongated. The metacone is more prominent and well preserved than the paracone (Fig. 2(3a)). The post-fossette is more developed than the pre-fossette and plicated with the enamel folding (Fig. 2(3c)). A vertical fracture is present in the metaloph which is poorly preserved. The protoloph is broken but the ectoloph is well preserved.

PC-GCUF 09/38 protocone is isolated, sub ovate in shape and broad at the apex. All the styles are strongly developed and prominent but the metastyle is broken at the base. The hypoconal groove is prominent. The hypocone is broad and well preserved than the paracone and the metacone. Both the pre- and the post-fossettes are clear and well developed. The metaloph and the protoloph are broken but the ectoloph is clear and well developed. The crown is thinly plicated.

PC-GCUF 09/40 is in an early middle wear. All the cusps are well developed and prominent (Fig. 2(4c)). The parastyle and the mesostyle are fused at the base and metastyle is broad at the base (Fig. 2(4a)). The paracone and the metacone are well developed and prominent. The hypoconal groove and the ectoloph are well preserved. The metaloph is broken. The fossettes are highly plicated (Fig. 2(4c)). PC-GCUF 09/41 protocone is isolated and damaged at the apex. A vertical crack is present in the metaloph. The protoloph and the ectoloph are prominent. All the fossettes are clear and the crown is highly plicated. The comparative measurements are provided in table 2.

Table 2. The comparative measurements (mm) of *Hipparion* sp. Referred material is taken from Bernor and Hussain (1985), Colbert (1935), Ghaffar (2005) and Iqbal *et al.* (2009). * The referred specimens.

Serial Number	Speci-mens	Width	Length	Height
PC-GCUF 09/37	M1	22	26	69
*PUPC 2000/99	M1	26	23	32.50
*PUPC 2000/99	M1	14.50	22	18
*GCS 07/19	M1	21.8	21.4	55.7
*GCS 07/23	M1	19.8	22.8	52.9
*GCS 07/57	M1	11.9	19.7	12.9
*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	-
*AMNH 19855	M1	15.0	24.5	-
*BMNH M 2647	M1	21.5	19.7	-
PC-GCUF 09/38	M2	22.3	25.4	67
PC-GCUF 09/40	M2	24	24	32
PC-GCUF 09/41	M2	23	22	43
*PUPC 2000/99	M2	26	24	35
*PUPC 2000/99	M2	15	22	16
*GCS 07/21	M2	19.95	20.8	52.6
*GCS 07/57	M2	11.6	18.75	15
*AMNH 19723	M2	22.5	22.5	-
*AMNH 19752	M2	22.0	23.0	-
*AMNH 19676	M2	22.0	21.0	-
*AMNH 19492	M2	21.5	20.0	-
*AMNH 19855	M2	14.0	25.0	-
*BMNH M 2647	M2	19.8	21.3	-

Discussion: *Sivalhippus theobaldi* has large sized molars (Fig. 3a-c; Appendix 1). *Hipparion* sp. are moderate in size and the enamel plication is complicated. The occlusal pattern of *Hipparion* sp. differs in many respects from *Sivalhippus theobaldi,* in a small size, complicated enamel plications and rounded to ovate isolated protocone. The studied specimens have complicated enamel plications with rounded to ovate shape isolated protocone and reveal all the features of the species *Hipparion* sp. as described by Falconer and Cautely (1849), Bernor and Hussain (1985), Colbert (1935), Ghaffar (2005) and Iqbal *et al.* (2009). The anteroposterior and the transverse diameter of the described material are slightly different from the referred material given by Ghaffar (2005) and Bernor and Hussain (1985). The studied specimens show all the morphological features of *Hipparion* sp. In addition, the metrical values of the specimens match to the already described samples of *Hipparion* sp., confirm their inclusion to the Siwalik *Hipparion* species *Hipparion* sp.

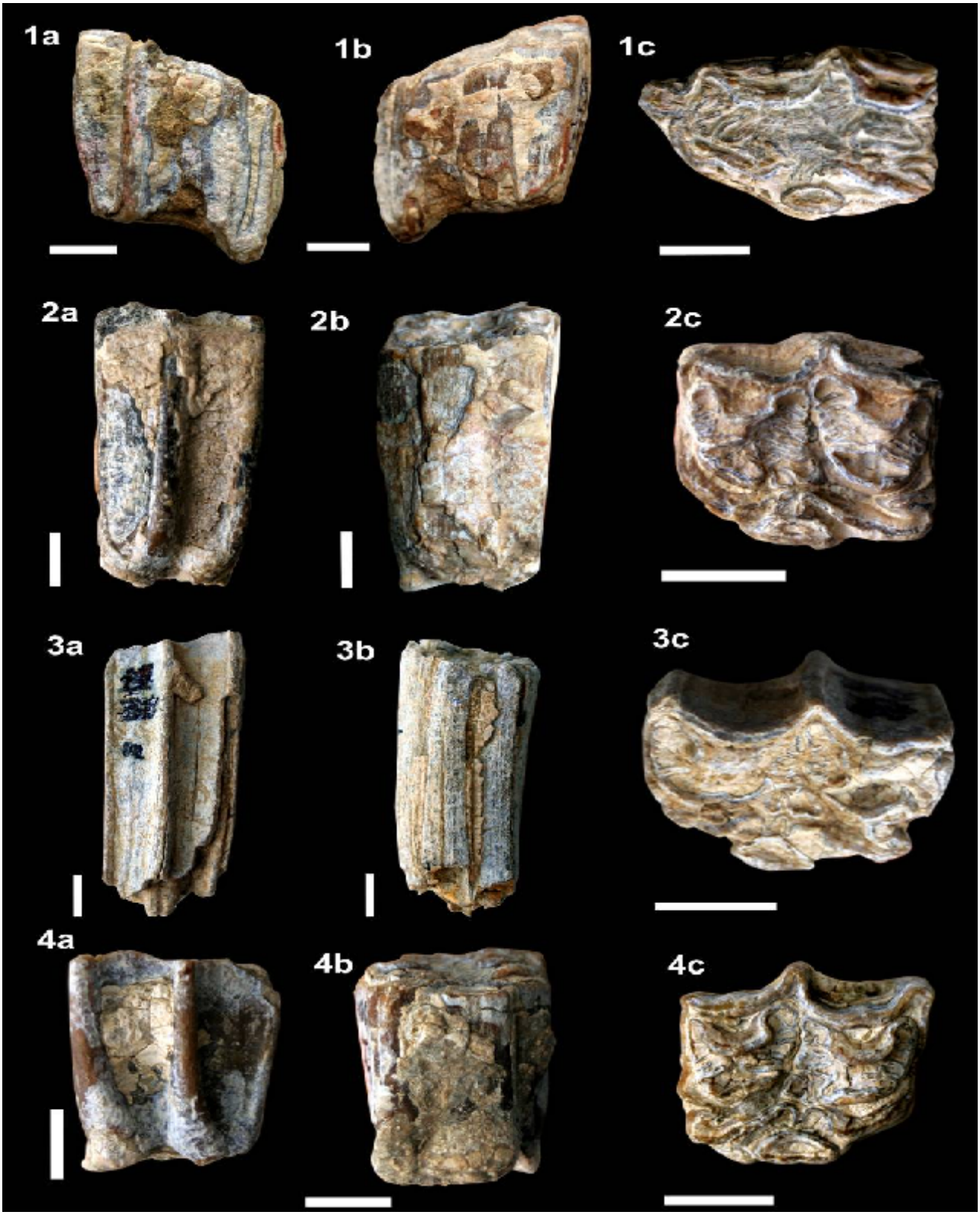

Fig. 2. *Sivalhippus* cf. *theobaldi*: 1. PC-GCUF 09/39 – lP2. 2. PC-GCUF 09/36 – lM2. *Hipparion* sp.: 3. PC-GCUF 09/37 – lM1. 4. PC-GCUF 09/40 – rM2. a = buccal view, b = lingual view, c = occlusal view. Scale bar equals to 10 mm.

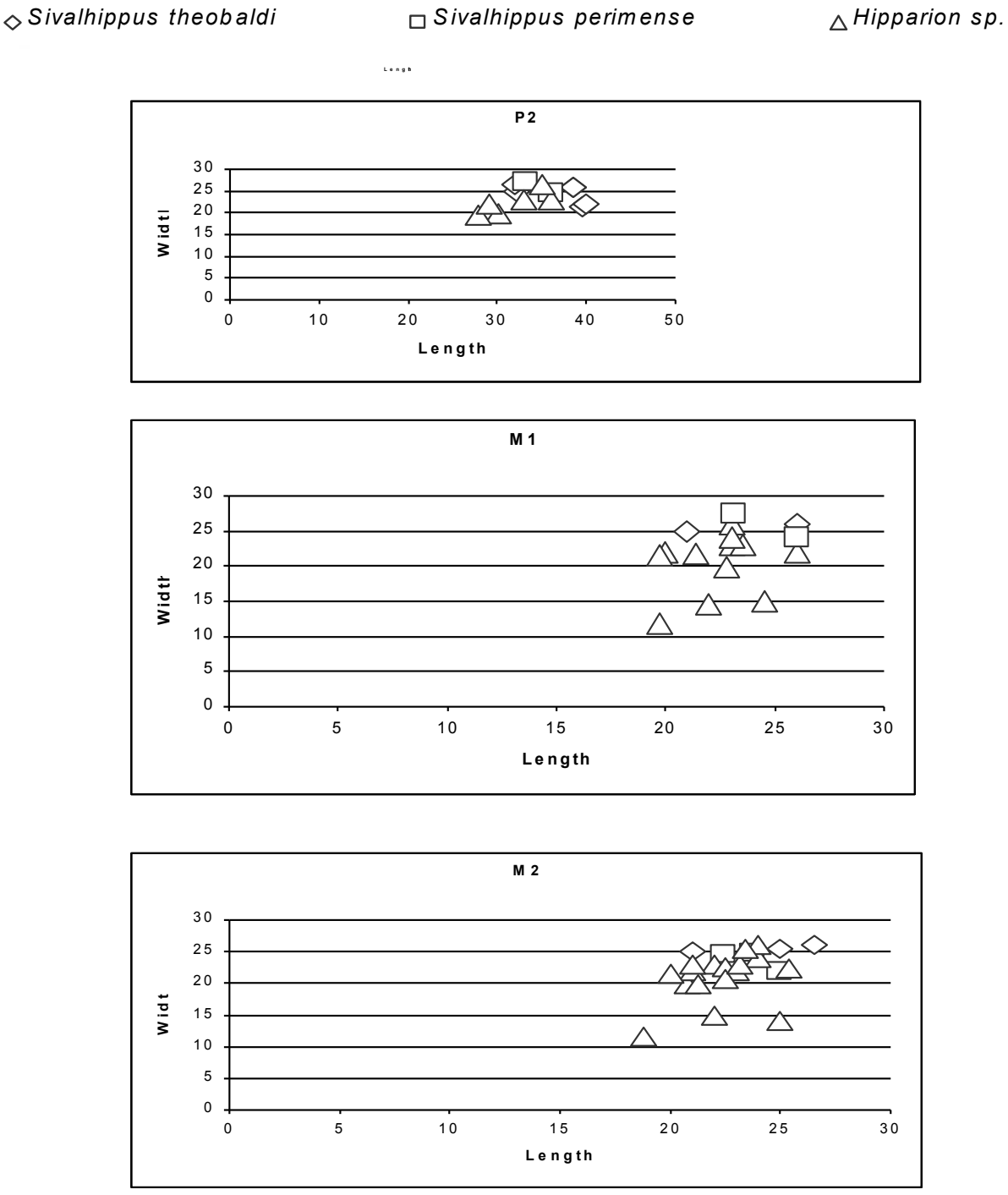

Fig. 3: Scatter diagrams showing the dental proportions of the Siwalik Hipparionine. The source data are taken from appendix 1.

Conclusion: The Siwalik Hipparionine group is evolutionary conservative and compares closely with *H. primigenum* and other primitive horses in complex cheek teeth fossette ornamentation, double or complex plicabllins, deeply incised hypoglyph and elongate P2 anterostyle. The *Hipparion* sp. and *Sivalhippus theobaldi* are significantly different in facial, dental and possibly postcranial features from species North American *Cromohipparion*. The Hipparionine has become circumscribed in its morphological characterization and the number of species included within this group. So, strictly working on the Siwalik hipparionines, the genus

Hipparion is considered valid by Ghaffar *et al*. (2003). Osborn (1918) considered *H. prostylum* to be the type species for genus *Hipparion* whose holotype comprises fragment palate having P4-M2. Since the original description, several species of *Hipparion* have been described from Old World and New World (Ghaffar, 2005). If the type of the habitat is judged on the basis of the composition of the fauna in which *Hipparion* has been found, the whole spectrum from pronounced forest to extreme steppe emerges. *Hipparion* is thus a rather broadly adaptive genus compared to the earlier equids and it would indicate a hypsodont genus of grazers and browsers.

In the Old World, *Hipparion* is only representative of the equidae during the Pliocene after *Anchitherium* became extinct during the beginning of the period, probably because of the lack of the competition it had the possibility to adapt to different environments. Other rates considered to be adaptive in animals maintaining themselves on abrasive food are: relative increase of occlusal surface of teeth, thicker enamel and increased resistance of the enamel and cement (Stirton, 1947; Van Valen, 1960). The limbs of *Hipparion* show typical changes in properties at the transition from mainly forest to steppe life. *Equids* are poor dispersers across water (Sondaar, 1977). *Hipparion* and *Equus* probably arrived in Britian over land, at a time when the island was connected to the Euorpean continent. *Hipparion* specimens have the most enriched carbon and oxygen values suggesting that it preferred more open, drier patches of the vegetation mosaic.

Different species of Hipparionine from the Siwaliks are chiefly based on teeth (Colbert, 1935). Lydekker (1883, 1887) considered *Hipparion* sp. closely related to *Hipparion gracile*. *Sivalhippus theobaldi* resembles European *H. crassum* in metapodial proportions. The upper cheek teeth of *Sivalhippus theobaldi*, although richly plicated and often crenulated, differ in having longer, oval protocones and the lowers have well developed protostylids and occasional ectostylids. The dental characters are common to late Miocene *Hipparion* in Eurasia and Africa and can be considered 'primitive' in relation to those of the European *H. crassum* group (Forsten, 2002).

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APPENDIX 1

Measurements (mm) of upper dentitions of *Sivalhippus perimense*, *Hipparion* sp. and *sivalhippus theobaldi.* The referred materials are taken from Pilgrim (1910), Falconer and Cautley (1849), Lydekker (1882), Ghaffar (2005), Bernor and Hussain (1985), Colbert (1935) and Naseem *et al*. (2009).

Taxa	Serial Numbers	Position	Width	Length	Height
Sivalhippus perimense	PUPC 86/178	P2	24.5	36	54
		M1	24.0	26.0	51
	AMNH 1976	M2	22.0	25.0	57
	GSI C349	P2	27	33.2	-
		M1	27.4	23.1	-
		M2	24.8	23.7	-
		P2	-	22	-
		M1	-	22.2	-
		M2	24.7	22.4	-
Hipparion sp.	PUPC 96/16	M1	-	22.1	-
		M2	-	23.2	-
	BMNH 15	M1	24.0	20.5	16
		M2	23.0	21.0	15
	PC-GCUF 08/16	M1	24.0	22.1	-
		M2	20.7	22.5	
	PC GCUF-08/10	M2	23.0	23.2	-
	PC GCUF 08/13	M1	19.4	23.0	-
		M2	25.5	23.4	-
	PUPC 2000/99	P2	23.0	36.0	22.0
	BMNH 2647	P2	19.9	30.1	-
	GCS 07/33	P2	19.4	27.8	49.6
	AMNH 19761	P2	26.5	35.0	-
	AMNH 19723	P2	23.0	33.0	-
	AMNH 19492	P2	22.0	29.0	-
Sivalhippus theobaldi	AMNH 19466	M1	26.0	26.0	-
	AMNH 19857	M1	25.0	21.0	-