Pakistan J. Zool., pp 1-5, 2021. **DOI**: https://dx.doi.org/10.17582/journal.pjz/20200206060215

New Fossil Collection of *Hippohyus sivalensis* (Artiodactyla: Suidae: Suinae) from Late Miocene to Pliocene of Siwaliks of Pakistan

Sadaf Aslam[1]*, Abdul Majid Khan[1] and Muhammad Akhtar[2]

[1]*Department of Zoology, University of the Punjab, Quaid-e-Azam Campus, Lahore*
[2]*Department of Zoology, Minhaj University, Lahore.*

ABSTRACT

The fossil remains of *Hippohyus* (Artiodactyla, Mammalia) from the Late Miocene/Pliocene of Middle and Upper Siwaliks are described. *Hippohyus sivalensis* is a common suid of late Miocene to Pliocene rocks of Tatrot/Hasnot area of Pakistan. The molar resemblance with equids indicates their grazing feeding habits. This species migrated to Potwar land when grasslands became established. It has typical suine characters with hypsodont dentition and complex infolding of enamel surfaces. The described material consists of isolated molars. This discovery will provide a new insight to understand the diversity and geographic distribution of Siwalik Suids.

Article Information
Received 06 February 2020
Revised 29 October 2020
Accepted 10 November 2020
Available online 15 Februay 2021

Authors' Contribution
SA is a principal author who conducted the research. AMK provided the lab and suggestions for article and MA provided the samples.

Key words
Suid, Suinae, Late miocene, Pliocene, Siwaliks, Pakistan

INTRODUCTION

Siwaliks are freshwater Neogene deposits of Himalayan foothills that extend from Pakistan to Bhutan passing through India and Nepal. It has three main divisions, Lower, Middle and Upper Siwaliks. Lower Siwaliks include Kamlial and Chinji formations. Middle Siwaliks include Nagri and Dhok Pathan formations. Upper Siwaliks include Tatrot, Pinjor and Boulder Conglomerate formations (Medlicot, 1864). The lower contact of Upper Siwaliks is not conformable with Dhok Pathan Formation and the upper contact ends in boulder bed with angular conformity. The Boulder Conglomerate Stage is defined by coarse and conglomeratic depositions that show the end of the Upper Siwalik series.

Suids are conspicuous elements from Miocene-Pliocene rocks of Siwaliks (Pilgrim, 1926; Matthew, 1929; Lewis, 1934; Colbert, 1935; Pickford, 1993). Suids belong to the family Suidae of order Artiodactyla, and include living members of that family that are similar to the ancestral form. Extinct fossilized species of suids contribute much in mammalian evolutionary studies as some provide a linkage through Anthracotheres to Cetacea (Sarwar *et al*., 2016). *Hippohyus* belongs to subfamily Suinae.

The specimens described here have been collected from different localities of Late Miocene to Pliocene of Upper Siwaliks of the Kotal Kund, Tatrot, Hasnot and Pinjor areas.

Hasnot (Lat. 32º 49' 27.89 N, Long. 73º 07' 52.68 E) is situated about 35 km west of Jhelum city in Potwar Plateau, Punjab, Pakistan. Deposits are mainly comprised of freshwater sedimentary rocks of Neogene age. This area was deposited at 5.3-3.5Ma (Late Miocene–Early Pliocene). Various suid fossils of the Dhok Pathan formation have been explored from Hasnot (Batool *et al*., 2015).

Lithologically, the Pinjor Formation is characterized by the alternation of brown and pink mudstones and grey-green sandstones. Mudstones are dull, concretionary and of brown pink in color. Sandstones are medium to coarse grained, soft to medium hard, current bedded and pebbly. Dips are low and beds can be traced along the strike and dip slopes form excellent sites for fossil collection (ohnson *et al*., 1982; Dennel *et al*., 2006).

The upper borderline of Pinjor stage is normally placed in the Early Middle Pleistocene, ca 0.6 My. All through this period, deposition was mostly seasonal, periodic and fine grained (Keller *et al*., 1977; Raynold and Johnson, 1985).

Tatrot and Kotal Kund (Lat. 32º 46' 0" N, Long. 73º 18' 0" E) belong to Tatrot Formation The fossiliferous deposits of the Tatrot Formation outcropping in the area consist of pale pinkish orange brown clays, brownish grey fine to medium grained sandstones intercalated with dark grey conglomerates. Hussain *et al* (1992) and Barry *et al* (2002) dated the lower boundary of the Tatrot Formation between 3.5-3.3 or 3.4-3.2 My wherease Kumaravel *et al*

* Corresponding author: sadaf.hons@pu.edu.pk
0030-9923/2021/0001-0001 $ 9.00/0

(2005), Dennel *et al*. (2008) and Nanda (2008) dated the upper boundary of the Tatrot Formation between 2.4-2.6 My. Thus Tatrot Formation roughly corresponds to the latest Pliocene.

MATERIALS AND METHODS

The material found, comprised of isolated molars of *Hippohyus sivalensis* from Upper Siwaliks, Pakistan. Determination at species level can be attempted by comparison with the material described by Pickford (1988). The specimens were collected simply by surface collection method during the various field work by the authors. The fossils are housed in the Abu Bakr Fossil Display and Research Center of the Department of Zoology, University of the Punjab, Lahore, Pakistan. The specimens catalogue in two series i.e. serial catalogue number and the year. The upper figure denotes the collection year, while the lower one denotes the serial number of the respective specimen. Measurements of the specimens are given in millimeters, and taken with the help of metric Vernier Calipers.

RESULTS AND DISCUSSION

Family: Suidae Gray, 1821
Subfamily: Suinae Zittel, 1893
Genus: *Hippohyus sivalensis* Falconer and Cautley in Owen 1840-45

Generic diagnosis

Suinae with hypsodont cheek teeth, without cement cover, short snout with relatively vertically implanted incisors. Parietal crests close together but not joined to form a saggittal crest. Molar and premolar enamel thin; furchen deep, forming complex infolding of enamel surfaces. No labial pillar in lower molars. Orbits and zygomatic arches situated further forwards than in *Propotamochoerus*. P3 with two labial main cusps and two ridges leading from labial cusp tips down lingual surface onto lingual cingulum (Pickford, 1988).

Geographic distribution

Hippohyus has only been recorded from Pakistan (Tatrot, Hasnot, Kotal Kund, Phta, Kolsa, Darapur, Jabi, Kakrala) and India (Pinjor) in a very Late Miocene to Pliocene sediments (ca. 5-2 Ma) (Pickford, 1988).

Hippohyus sivalensis Falconer and Cautley

Synonym list

1840-45 *Hippohyus sivalensis* gen. et. Sp. nov. Falconer and Cautley, in Owen, *Sus* (*Hippohyus*) *sivalensis* (F and C) Falconer, 1879 *Hippohyus* F and C. Lydekker, *Hippohyus grandis sp*. nov. Pilgrim.

Specific diagnosis

A species of *Hippohyus* of large size with upper molar row longer than 65mm.

Holotype: Specimen illustrated in Owen, (1840-45) PI. CXL.

Horizon: Upper Siwaliks and Middle Siwaliks.

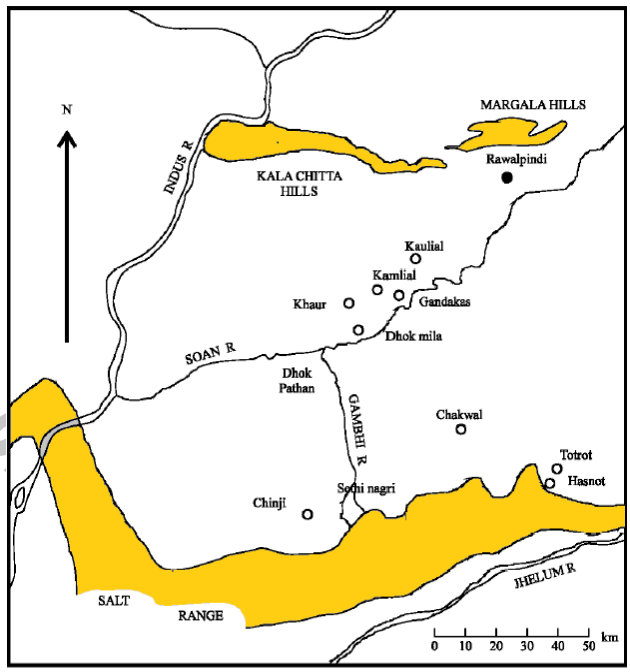

Fig. 1. Map of the study section showing main fossil localities.

Studied material

Upper dentition

1. PUPC 97/89 (Fig. 3, Table I), an isolated broken upper right third molar, collected from Tatrot, district Jhelum, Punjab province, Pakistan.

2. PUPC 15/39 (Fig. 2, Table I), an isolated upper left first molar, collected from Pinjor, district Jhelum, Punjab province, Pakistan.

3. PUPC 15/350 (Fig. 2, Table I), an isolated upper left third molar, collected from Hasnot, district Jhelum, Punjab province, Pakistan (Fig. 5).

4. PUPC 15/21 (Fig. 3, Table I), an isolated upper left second molar, collected from Kotal Kund, district Jhelum, Punjab province, Pakistan (Fig. 5).

5. PUPC 15/356 (Fig. 2, Table I), an isolated upper left first molar, collected from Hasnot, district Jhelum, Punjab province, Pakistan (Fig. 5).

Table I. *Hippohyus sivalensis* (*Referred data taken from Pickford, 1988; Batool *et al.*, 2015).

Specimen	Posi-tion	Length (mm)	Width (mm)	Height (mm)	W/L index
PUPC 97/89	rM3	25.7+	16.4	14.2	0.63
PUPC 15/39	lM1	20.2	18.0	8.7	0.89
PUPC 15/350	lM3	34.1	19.8	10.0	0.58
PUPC 15/21	lM2	26.6	21.2	12.9	0.79
PUPC 15/356	lM1	20.7	17.7	10.0	0.85
PUPC 16/92	rm1	18.0	13.1	10.1	0.72
*B66	M3	35	22.7	-	0.64
*K33	M3	33.5	21.4	-	0.63
*B720	M3	38	24.5	-	0.64
*B722	M1	17.5	16.6	-	0.94
*K/601	M1	22.6	17.6	-	0.77
*B722	M2	28	21.5	-	0.76
*K 15/914	M2	24.6	19.8	-	0.80
*K13/922	M2	24.3	21	-	0.86
*B721	m1	20	12	-	0.6
*PC-GCUF 12/48	lM2	23.4	19.0	-	0.81
*PC-GCUF 12/22	lM3	32.1	20.4	-	0.63

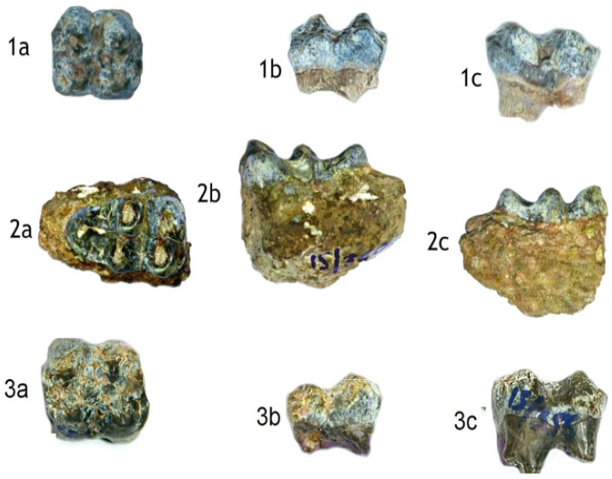

Fig. 2. *Hippohyus sivalensis.* Upper dentition: 1, PUPC 15/39, lM1; 2, PUPC 15/350, lM3; 3, PUPC 15/356, lM1; a, occlusal view; b, lingual view; c, buccal view; scale bar, 10mm.

Lower dentition

PUPC 16/92 (Fig. 4, Table I), an isolated lower right first molar collected from Tatrot, district Jhelum, Punjab province, Pakistan (Fig. 5).

Fig. 3. *Hippohyus sivalensis.* Upper dDentition: 1, PUPC 15/21, lM2; 2, PUPC 97/89, rM3; a, occlusal view; b, lingual view; c, buccal view; scale bar, 10mm.

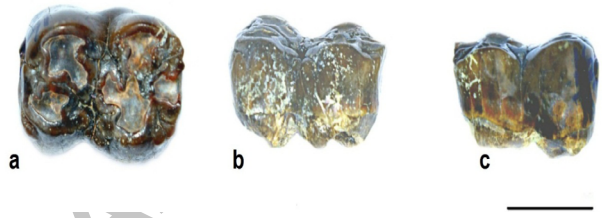

Fig. 4. *Hippohyus sivalensis.* 1. lower dentition: pupc 16/92 rm1; a, occlusal view; b, lingual view; c, buccal view. Scale bar, 10mm.

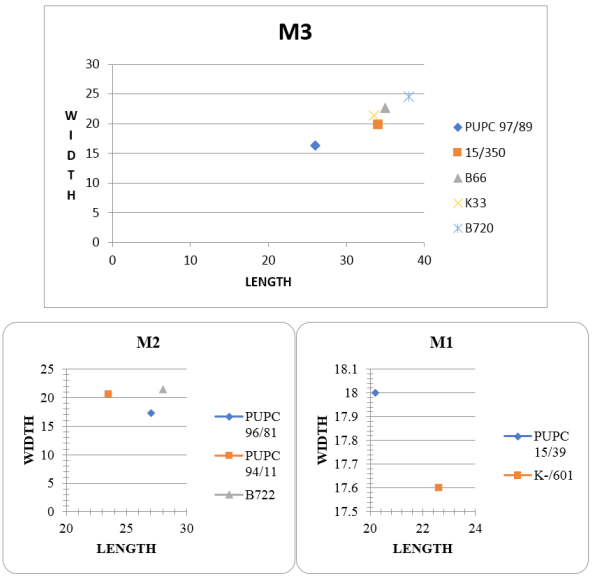

Fig. 5. Scatter diagrams of cheek teeth of *Hippohyus sivalensis.* Comparative measurements have been taken from Pickford 1988.

Stratigraphic and geographic distribution of the present material

Kotal Kund, Tatrot, Hasnot, Pinjor. Upper Siwaliks; Late Miocene to Pliocene.

Description

Upper dentition

Upper first molar (PUPC 15/39, Fig. 2, Table I) consists of four main blunt cusps. Thick flare of cingulum is present. Median accessory cusp is present in the median valley. Median basal pillar is present at the end of median valley on one side. Enamel is thick. Main cusps are characterized by three furchen leading into sagittal valley anteriorly and posteriorly.

Upper second molar (PUPC 15/21, Fig. 2, Table I) consists of four main cusps. Anterior, posterior and median accessory cusps are prominent along with anterior and posterior cingulum. A marked feature of the molar is the considerable mesiodistal undercut in the molar, so that the crown is considerably longer at the tip than it is at the cervix. The median valley is broad having broader medium accessory cusp. Median basal pillar present lingually and labially at the end of median valley.

Upper third molar (PUPC 97/89, Fig. 3, Table I) is 4 cusped tooth with talon. Small portion of anterior cusps are broken. Median accessory cusp is visible. Enamel is rugose. PUPC 15/350 (Fig. 2) is large tooth with 4 main cusps (Table I). Anterior and posterior cusps are lophodont. Paracone is broken. Tooth is in middle stage of wear. Dentine is visible on top. Thin layer of cingulum is present anteriorly and posteriorly it expands to form broad talon. No accessory cusps are visible. Talon is marked laterally by cingular cusplets.

Lower dentition

Lower first molar (PUPC 16/92, Fig. 4, Table I) is four cusped tooth. It contains main features of genus *Hippohyus*. Median accessory cusp is present in the median valley. Median basal pillar is present. Moderately thick enamel is present. Thick flare of cingulum surrounds the tooth.

Comparison and discussion

Specimens have been assigned to *H. sivalensis* due to thin enamel, deep furchen, basic outline of the molar and complex infolding of enamel surfaces.

Pilgrim (1926) described *Hippohyus sivalensis* based upon complete skull. It has never been recorded from the Nagri and Dhok Pathan formations, but is common in Tatrot /Hasnot areas. It is a late Miocene to Pliocene form. It is often found with *Sivahyus*, *Sivachoerus*, and *Sus*, and occasionally with large from of *Hippopotamodon sivalensis*.

The skull morphology was similar to that of *Propotamochoerus* with some differences. The front half of the skull of *Hippohyus* is shorter than that of *Propotamochoerus* because its snout is remarkably shortened and no diastema is present. However, the dentition of *Hippohyus* is different from that of *Propotamochoerus*. Crown of the upper incisors and canine are little known. The cheek teeth are better known and comparatively higher crowned than those of *P. hysudricus*. First and second upper premolars are poorly known. Third upper premolar consists of single main cusp along with anterior and posterior accessory cusps. The ridges of lingual cingulum are different from those of *Propotamochoerus*. P4 is much more similar to that of *Propotamochoerus*, with two main labial cusps, a lingual main cusp, two sagittal cusplets and anterior and posterior cingula. Molars are also homologous to those of *Propotamochoerus*. Enamel thickness of *Hippohyus* and *Propotamochoerus* is also comparable. The molars consist of four main cusps, anterior, median and posterior cingula. No basal pillars are present; however, in *Propotamochoerus* variable basal pillars are present on labial side of median valley in *Sivahyus*. Last molar has relatively simple and hypsodont talon. Thus, *Hippohyus* differs from *Propotamochoerus* by having shortened snout, vertical incisors and relatively hypsodont molars instead of long snout, procumbent incisors and low crowned molars with shallow furchen in *Propotamochoerus*. These differences might reflect evolution due to diet modification. Superficially *Hippohyus* molars resemble *Equus* molars and this might be due to their comparable foods. The presence of deep furchen in molars effectively increases the length of cutting edge. Thus, it is postulated that *Hippohyus* was probably grazer rather than browser or omnivore. Thus, it is suggested that *Hippohyus* evolved after the grass cover become significant.

Hippohyus sivalensis differs from *Hippohyus lydekkeri* mainly in size and hypsodonty. There is also difference of canine morphology due to sexual dimorphism. *H. sivalensis* is greater than *H. lydekkeri* but there are few specimens of *H. lydekkeri* that have the size of *H. sivalensis*. *H. lydekkeri* is less hypsodont as compare to *H. sivalensis* so it is reliable criteria to separate the two species of *Hippohyus*. The mandible of *H. sivalensis* is suine except in shortening of the symphysis and implantation of the incisive battery is more vertical (Lydekker, 1884). Moreover, *H. lydekkeri* is Pliocene species. This work supports the work of Pickford on *Hippohyus*.

CONCLUSION

Hippohyus sivalensis is a late Miocene to Pliocene suid found in Middle and Upper Siwaliks. It is grazing species of suids adapted to grassland habitat. This study will help to understand origin and dispersal of Siwalik Late Miocene to Pliocene suids.

Statement of conflict of interest

The authors have declared no conflict of interest.

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