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Article

ON THE OCCURRENCE OF *ANANCUS SIVALENSIS* FROM THE TATROT FORMATION (PLIOCENE) OF UPPER SIWALIKS OF INDIAN SUBCONTINENT

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ABSTRACT – The Siwaliks are worldwide known for its fossil primate remains. Several fossil prosimians and hominoids, including *Sivapithecus*, *Sivaladapis*, and *Gigantopithecus*, have been discovered in the Siwaliks of the Indian Subcontinent. Additionally, many fossil mammals have been found in the area under study. This paper presents the first finding of a well-preserved upper molar of *Anancus sivalensis*, which was collected from the Tatrot Formation (Pliocene) of the Upper Siwalik deposits at Khera Village near Kala Amb in Himachal Pradesh, India. The dental remains suggest that *Anancus sivalensis* was a grazer. The mammalian fauna indicates that the Tatrot bed of the Upper Siwaliks in this region dates back to the early Pliocene. The present paper deals with the systematic description of the fossil material of *Anancus*. The Tatrot deposit of the Upper Siwaliks in the region is thought to date early Pliocene based on the mammalian faunal composition. However, some comments about the palaeoecological conditions in the form of the habitat spectra have also been included, which indicate a more open landscape with bushland, grassland and scattered wood cover.

Keywords: *Anancus,* Upper Siwaliks, Pliocene, dental remains, Palaeocology, India.

INTRODUCTION

The Indian Subcontinent's Upper Siwaliks, which are exposed in the states of Haryana and Himachal Pradesh, have produced a diverse array of extinct mammals, including gompotheres (Gaur, 1987; Kumar, 2009, 2014, 2022; Kumar & Gaur, 2013, 2015, 2024). Numerous authors have previously conducted research on fossil proboscideans from the Siwaliks, including Osborn (1936), Chakravarty (1965), Aguirre (1969), Maglio (1973), Nanda (1976, 1977), Sarwar (1977), Tassy (1983), Ganjoo (1985), Gaur (1986, 1987), Rai (2004), Khan *et al*. (2011), Kundal *et al*. (2017), and Kumar & Chauhan (2023). In particular, the extinct gomphothere *Anancus*, named by Aymard (1855), was widespread during the Pliocene and persisted until the Early Pleistocene. Anancine gomphotheres originated in Eurasia, most likely deriving from *Tetralophodon* (Falconer, 1857), and were widely distributed throughout the Old World during the late Miocene - early Pleistocene (Tobien, 1973; Sarwar, 1977; Coppens *et al*., 1978; Madden 1983; Mebrate & Kalb, 1985; Tassy, 1985; Tobien *et al*., 1988; Metz-Muller, 1995; Kalb *et al*., 1996; Shoshani, 1996; Göhlich, 1999, Hautier *et al*., 2009).

In Eurasia, the genus *Anancus* was represented by three species: *A. arvernensis* (Croizet & Jobert, 1828), *A. alexeevae* Baigusheva, 1971, and *A. kazachstanensis* Aubekerova, 1974 (Bajgusheva, 1971; Alekseeva, 1977). In Africa, the genus *Anancus* includes five species: *A. kenyensis* MacInnes, 1942, *A. ultimus* Sanders, 2011, *A. capensis* Sanders, 2007, *A. petrocchii* Coppens, 1965, and *A. osiris* Arambourg, 1945 (MacInnes, 1942; Arambourg, 1945; Coppens, 1965; Sanders, 2007, 2011). In Asia five species of the genus *Anancus* are recognized, namely *A. sinensis* Hopwood, 1935 and *A. cuneatus* Teilhard de Chardin & Trassaert, 1937 from China (Hopwood, 1935; Teilhard de Chardin & Trassaert, 1937). In the Siwaliks of India and Pakistan, the fossil taxon *Anancus* is represented by two species, *A. sivalensis* (Cautley, 1836), *A. perimensis* (Falconer & Cautley, 1846), and *A. kazachstanensis* from Kazakhstan (Cautley, 1836; Falconer & Cautley, 1846; Aubekerova, 1974).

Until this study, there was no published record of *Anancus sivalensis* from the Upper Siwaliks of India. The Upper Siwaliks of the Indian Subcontinent, exposed near Naraingarh Town in Haryana, have revealed a rich collection of fossil animals, however, *Anancus sivalensis* is extremely rare in compared to other proboscidean fossil fauna (Gaur, 1987; Kumar, 2009). This study presents the first record of *Anancus sivalensis* from the Indian Siwaliks, and it adds to our understanding of this extinct *Anancus* species that was previously known only from the Pakistan Siwaliks.

MATERIAL AND METHODS

The present contribution is based on the fossil specimen of *Anancus sivalensis* collected from the Tatrot sediments of the Khera Village near Kala Amb of Himachal Pradesh, India. The dental specimen reported here was collected by the author (SK) during his doctoral research work. The specimen considered in this article, PUA/SK- 07/64, is a left maxillary third molar discovered *in situ* from a greyish mudstone layer of the Tatrot Formation,

exposed southeast of Khera Village (Figures 1 and 2). The referred specimen was discovered together with various Pliocene mammalian species, including *Hexaprotodon sivalensis*, *Sus*, *Leptobos falconeri*, and yet-to-be-identified Bovini (Figure 2).

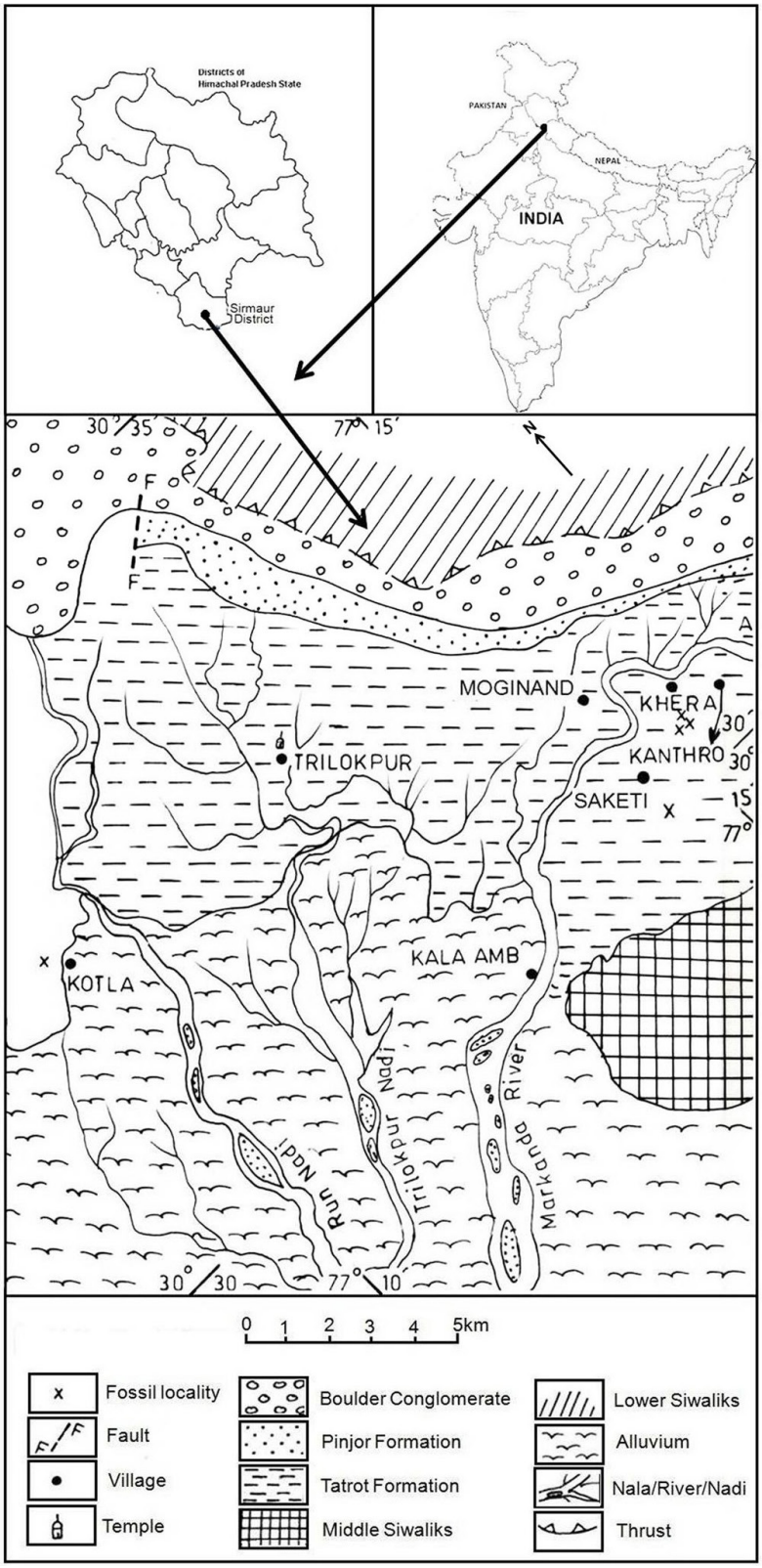

Figure 1. Generalized locality map of the area (after Kumar & Gaur, 2013).

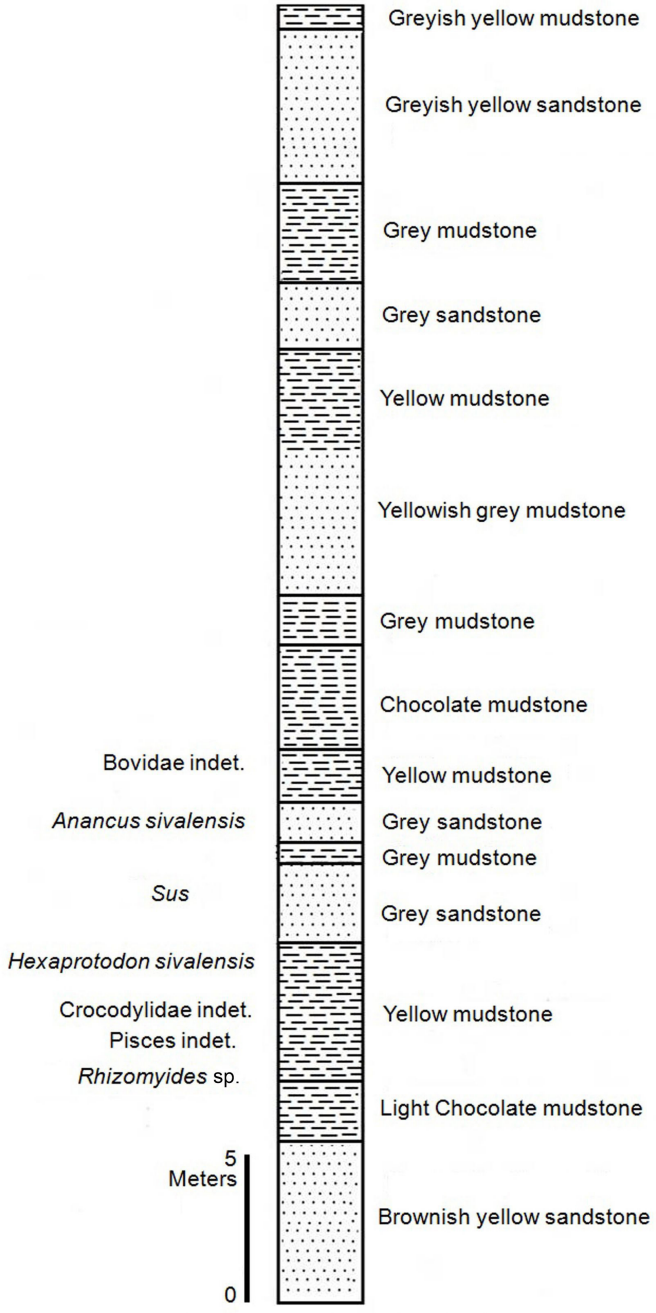

Figure 2. Local stratigraphic section of the Tatrot Formation of the locality.

According to the Dennell *et al*. (2006), the Upper Siwaliks of the Indian Subcontinent span the Late Pliocene to Middle Pleistocene time interval (3.3–0.6 Ma). No radiometric dates are as yet available for the Tatrot Formation of India. Only a scanty magnetostratigraphic data is available in India, while the majority of magnetostratigraphic research was carried out in the Siwaliks of Pakistan (Nanda, 2013). In the Indian Siwaliks the first magnetostratigraphic investigations of the Upper Siwaliks near Saketi and in the Chandigarh region were conducted by Azzaroli & Napoleone (1982) and Tandon *et al*. (1984), and these authors placed the Tatrot/Pinjor formational boundary at the Gauss/Matuyama transition at about 2.5 Ma. More recently, biostratigraphically, Dennell *et al*. (2006) and Nanda (2008) placed the upper boundary of the Tatrot Formation between 2.4 and 2.6 Ma. A radiometric age of 2.53 Ma was assigned by Johnson *et al*. (1982) for the Upper Siwaliks of Pakistan, which helped to identify the boundary between the Gauss and Matuyama magnetic chrons that is considered to mark the transition between the Tatrot and Pinjor formations (Opdyke *et al*., 1979; Johnson *et al*., 1982; Barry *et al*., 1982; Hussain *et al*., 1992; Nanda, 2002). The mammalian faunal assemblages found in the Tatrot Formation of the Upper Siwaliks indicate an Early Pliocene age (Gaur, 1987).

SYSTEMATIC PALEONTOLOGY

MAMMALIA Linnaeus, 1758
PROBOSCIDEA Illiger, 1811
ELEPHANTIFORMES Tassy, 1988
ELEPHANTOIDEA Gray, 1821
GOMPHOTHERIIDAE Hay, 1922
ANANCINAE Hay, 1922

Anancus Aymard, 1855

Type species. *Anancus arvernensis* (Croizet & Jobert, 1828).

Anancus arvernensis (Croizet & Jobert, 1828)

(Figure 3)

Diagnosis. Gomphotheriid with a high, short skull. Elevated dome. Enlarged tympanic bulla. Short mandible without tusks. Straight upper tusks without enamel. Loss of premolars. Tetralophodont intermediate molars (occasionally pentalophodont M^2). Pretrite posterior central conule reduced in upper molars. Reduction of the pretrite anterior central conule on the lower molars and fusion with the mesoconelet. Alternation of the pretrite and postrite half-loph(id)s (anancoidy) allows the establishment of an alternative contact of successive loph(id)s, especially for the lower intermediates and M_3. The upper third molar has five or six lophs and shows a trend towards simplification (after Tassy, 1986; Hautier *et al*., 2009 and Garrido & Arribas, 2014).
Referred material. PUA/SK – 07/64, a left maxillary third molar.
Horizon. Upper Siwaliks, Tatrot Formation.
Locality. About 0.70 km south of Khera Village, near Kala Amb of Himachal Pradesh, India.

Description. The newly referred specimen PUA/SK-07/64 is a well-preserved left maxillary third molar (Figure 3). The molar is slightly damage on its mesial and distal ends and has some chipping of the enamel on the lingual side at the cervical margin. The occlusal aspect of the molar shows five ridges. The last ridge is smaller and is placed at a comparatively lower level than the first five ridges. The anterior three ridges are more worn than the posterior three ridges which are almost unworn. The valley between the ridges is filled with a thin layer of cement, which has eroded at several places. The median transverse valleys are by a large blocked by a central conule. The pretrite and postrite cones alternate and are placed diagonally rather than transversely, which is a characteristic feature of the family Brevirostrinae (Osborn, 1936).

On the lower side, the molar shows massive roots, which are slightly inclined towards the posterior side. The roots of the last three ridges have fused into one massive root. The enamel is smooth and thick. The enamel thickness is approximately 7.1 mm. The maximum length of the referred molar is 178 mm, and its maximum breadth is 81 mm (Table 1). The lamellar frequency of the molar is about 3.37 mm. The number of aristogenes in the molar is approximately 22. The color of the enamel is light yellowish-brown.

Most of the crown details of the first ridge have been obliterated on account of excessive wear particularly towards the anterior side. The postrite and pretrite cones have been completely worn down and only a portion of posterior enamel border is present. The enamel of postrite and pretrite are confluent with each other, is broken on the buccal and lingual sides. The posterior enamel of the first ridge is tightly pressed against the anterior enamel of the second ridge, more so with the pretrite. Due to heavy wear, the valley between the first and second ridge has been reduced to a shallow depression on the lingual side. The central conule is very small and has become confluent

Table 1. Comparative measurements (mm) of maxillary third molar of some species of *Anancus*. *estimated.

Measurement	Present specimen	*Anancus sivalensis* Osborn (1936)			*Anancus Falconei* Osborn (1936)	*Anancus khetpuraliensis* Nanda (1977)	*Anancus Arvernensis mencalensis* Garrido & Arribas (2014)	*Anancus kenyensis* Tassy (1986)	*Anancus sinensis* Chen (1999)
	PUA/SK 07/64	(P.651)			(P.653)	CASGF 316	FSCC-3-001	KNM-LU R795	PMU M 3662
Max. mesio-distal diameter (L)	178.00	164.00	166.00	178.00	200.00	179.00	166	170	203-220
Max. bucco-lingual diameter (B)	81.00	76.00	75.00	--	84.00	72.00	74.06	77	83-98
Index (B/L X 100)	45.50	46.34	45.18	--	42.00	40.22	44.61	45.88	40.5-45
Max. crown height	55.01	--	--	--	--	--	64.7	55.6	-
Crown Height Index (H/W X 100)	67.00	--	--	--	--	-	87.36	72.20	-
Ridge Crests	6 ½	5	5½	½ -5- ½	7½	6 ½	6	5	-
Number of Aristogenes	22*				27*	25*	-	-	-
Enamel thickness	7.02	-	-	--	-	7.0	-	-	-
Ridge crest per 100mm	3.37	3.05	3.75	--	3.75	3.60	-	-	-

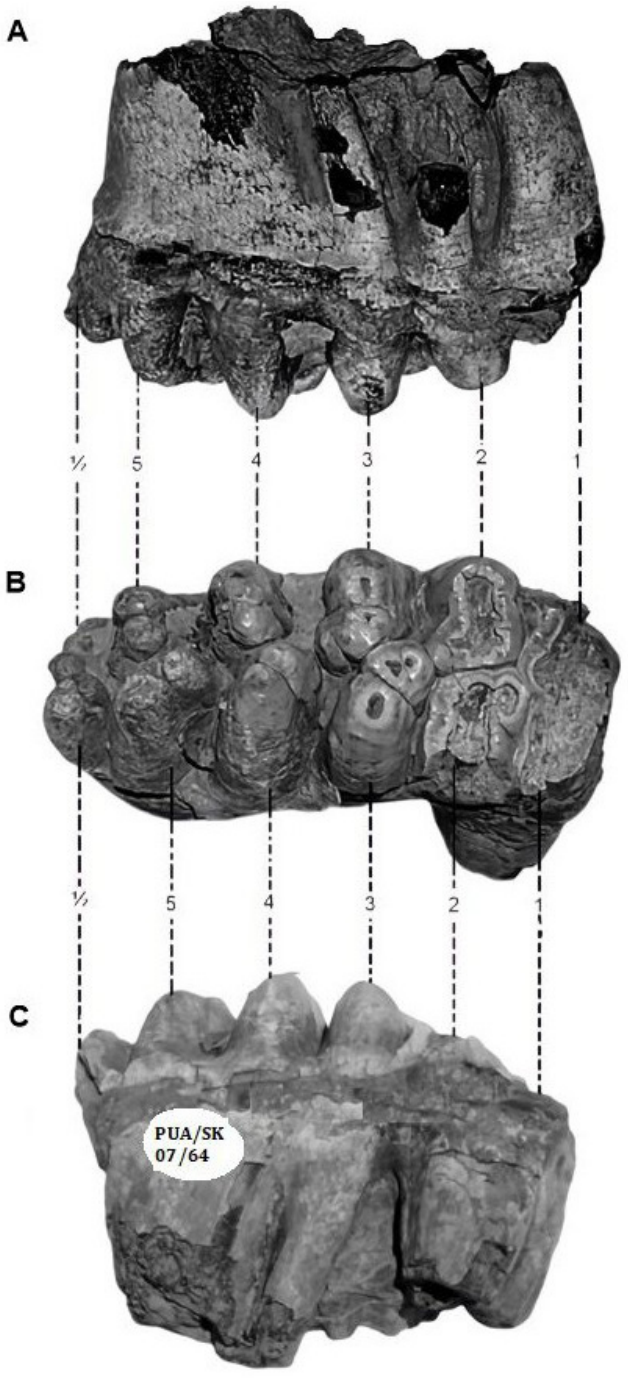

Figure 3. PUA/SK-07/64, a left maxillary third molar of *Anancus sivalensis* in **A**, buccal, **B**, occlusal and **C**, lingual views. Scale bar = 2 cm.

with the postrite due to heavy wear. The second ridge shows two distinct cones. The pretrite is less worn than the postrite. The enamel of the postrite is broken along the buccal side. The enamel of both postrite and pretrite is thick and shows slight folding. Posterior to the second ridge a well-developed central conule blocks the valley between second and third ridge. This central conule shows slight wear. The valley between the pretrite of second and third ridge is broad and deep, while the valley between the postrite of second and third ridge is very narrow and shallow. The third ridge is much less worn and shows separate postrite and pretrite. A strong central conule which is placed slightly external to the midline, blocks the valley between the third and fourth ridge. The valley between the third and fourth ridge is broad and deep on the lingual side. It is filled with a layer of abundant cement. The valley between the postrite of third and fourth ridge is comparatively narrow and shows less

cement. The fourth ridge is similar in structure to the third ridge and shows traces of wear on the postrite and the central conule. The lingual side shows two small but distinct cones which form the pretrite. The enamel on the anterior side of both the cones is smooth while the posterior side enamel is somewhat rough. The central conule is isolated and placed slightly external to the midline and is smaller than that between third and fourth ridges. The central conule partly blocks the transverse valley between the fourth and fifth ridges. The valley is wider and deeper on the lingual side and is partly filled with cement. Like the fourth ridge the fifth ridge also shows no signs of wear. It consists of three cones. The postrite is distinctly larger than the pretrite. In between the postrite and pretrite a strong third cone is also present. The valley between the fifth and sixth ridge is open and partly filled with cement. The last ridge lies at a lower level than the first five ridges. The postrite is larger than the pretrite. The central conule is very small and is almost attached to the postrite. Two small conule's are present on the distal side of the sixth plate between the pretrite and postrite. The enamel on the disto-buccal side of the molar is chipped.

DISCUSSION AND COMPARISONS

The genus *Anancus* emerged in the late Miocene and persisted until the late Pliocene of Siwaliks when it perished (Sarwar, 1977; Khan *et al*., 2011). The record of anancine gomphotheres comes from Perim Island, Haritalyangar, India and the Potwar Plateau, Pakistan (Osborn, 1936; Sarwar, 1977). *Anancus* fossils have been recovered in Europe, Africa, and Asia. The genus *Anancus* includes the following species: *A. kenyensis*, *A. petrocchii*, *A. sivalensis*, *A. perimensis*, *A. osiris*, *A. sinensis*, and *A. kazachstanensis*, and it is represented by two species in the Indian Siwaliks: *A. sivalensis* and *A. perimensis*. The presence of *A. sivalensis* in the Pliocene of the Siwaliks is uncommon compared to the abundance of elephant bones. Sarwar (1977) described a tiny tooth fragment (PUPC 67/290, originally UZ 67/290) of *A. sivalensis* from the Tatrot Formation in Pakistan's Upper Siwaliks. There has been no record of maxillary molars from Upper Siwaliks regarding *Anancus sivalensis* until now. This is the first account of an extinct taxon from the Tatrot Formation of the Upper Siwaliks of the Indian subcontinent.

The problem of the boundary between the Pliocene and Pleistocene is still quite uncertain, from both a geological and a faunal perspective. The referred specimen (PUA/SK-7/64) varies from *Synconolophus* by having three transverse cones. *Anancus* differs from *Synconolophus* in that it has three primary transverse cones, whilst the latter two have four (Sarwar, 1977). The present specimen can be recognized from *A. falconeri* by its lower number of aristogenes (Table 1). *A. falconeri* has 27 aristogenes, whereas *A. sivalensis* has 22 (Osborn, 1936, p. 651). Furthermore, unlike *A. falconeri*, it has fewer ridges. *A. falconeri* has 7½ ridges, while *A. sivalensis* can have up to 6½ ridges (Osborn, 1936, p. 651). It varies from *A. falconeri* in that its ridges are not as close together. In *A. falconeri*, the ridges are more tightly spaced (7½ ridges in 200mm), but in *A. sivalensis*, they are rather wide apart (5 ridges in 164mm) (Osborn, 1936). The specimen features 5½ ridges in 178mm. *Anancus* upper third molars (Table 1; Figure 4) may have five to seven lophs. The amount of lophs is thus highly varied; the more worn a tooth is, the more prominent the anancoidy appears, particularly in

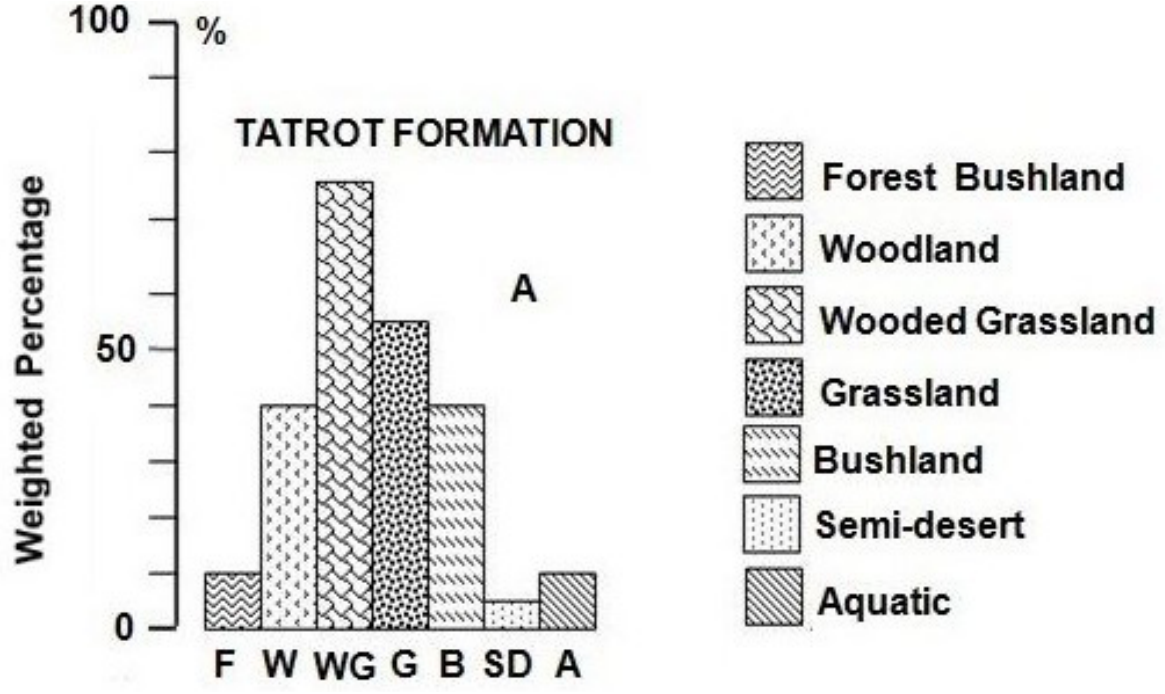

Figure 4. Habitat spectra analysis of Tatrot mammalian fauna showing major habitats (modified after Gaur & Chopra, 1984; Gaur, 1987).

specimens with advanced wear. These comparisons support the assignment of the specimen here presented to *Anancus sivalensis.*

PALEOECOLOGICAL CONDITIONS DURING TATROTS

Woodland and open woodland environments were prevalent in the Indian Subcontinent's Middle Siwaliks (Gaur, 2016). During Pliocene, the landscape started changing and the more wooded conditions of the Miocene time changed to more open country conditions, with distinctly less tree cover. Researchers, such as Gaur & Chopra (1984), Gaur (1987, 2016), utilized the habitat spectra analysis of mammalian fauna of Upper Siwalik deposits (Figure 4) to reconstruct the paleoecological and paleoenvironmental conditions of this area and concluded that the Tatrot climate was less humid than the Middle Siwaliks and its landscape largely consisted of scattered tree cover with bushland and some grassland areas. The grazing diet was proposed for *Anancus* species from the Pliocene of India based on isotopic analysis (Patnaik *et al*., 2019). The dental remains indicate that *Anancus sivalensis* was a herbivorous grazer.

CONCLUSIONS

Previously, no further species of *Anancus sivalensis* have been reported from India's Upper Siwaliks. This study expandes the range of the genus *Anancus* to include the Tatrot Formation (Pliocene), which was only known from the Perim Island (Middle Siwaliks), of the Indian Subcontinent. The referred specimen is significant as it represents the first report of *Anancus sivalensis* from this area in the Indian Subcontinent.

DATA AVAILABILITY STATEMENT

The author confirms that the data supporting the findings of this study are available within the article.

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AUTHOR CONTRIBUTIONS

Suresh Kumar has done drafting and all the work done in this manuscript.

DECLARATION OF AI USE

Author has not used AI-assisted technologies to create, review, or any part of this article.

ETHICS

This work does not require any ethical approval.

CONFLICT OF INTEREST

No potential conflict of interest was reported by the author.

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