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Microfossils based Palaeoecology and Palaeocommunity Structure of Upper Siwalik Deposits of Jammu, JandK, India

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Abstract

In this paper, the author built up the palaeo community structure of the study area by carried out palaeoecological analysis of collected microfauna and floras from the Late Pliocene Siwalik deposits of Jammu province. The collected microfauna and flora specimen comprises of microfossils (ostracods), micro vertebrates (rodents, fishes, frogs, lizards, snakes), invertebrates (gastropods and bivalves) and plants charophyte. The palaeoecological evidence indicates that during Late Pliocene times there were two dominant important communities' i.e. aquatic community (fresh water) and terrestrial community.

Keywords: Microfossils, Palaeoecology, Palaeocommunity Structure, Upper Siwalik deposits, Jammu and Kashmir, India.

Introduction

The fresh water molasses sediments (Middle Miocene to Middle Pleistocene) in the extra-peninsular India lying between Line of Actual Control in the west and Ravi River in the east (India) are known as the Siwalik deposits of Jammu. All the seven units (Kamlial, Chinji, Nagri, Dhokpathan, Tatrot, Pinjore and Boulder conglomerate) of Siwalik Group of rocks designated by Pilgrim[1] which are more or less used till date are well exposed as outcrops in the Jammu region. These outcrops are rich in fossil wealth. In the last fifty years, a number of workers have carried out works on the Upper Siwalik Subgroup of Jammu for microfossils/micro vertebrate's angles. The prominent workers may be made of Suneja and Kumar[2], Suneja et al[3], Rage et al[4], Gupta and Prasad[5], Bhatia et al[6], Prasad et al[7], Bhandri and Kundal[8], Kundal and Prasad[9], Kundal[10] and Kundal[11].

All these workers carried out work on taxonomy, age, biochronology and depositional environment of the Upper Siwalik deposits of Jammu. Suneja and Kumar[2] initiated the study of microfossil, micro vertebrates in the Upper Siwalik Subgroup of Jammu and discovered some teeth of crocodilian, teeth of fishes, spines, vertebrae from localities very near to Jammu. Suneja and his co-workers[3] recovered some species of charophyte and ostracodes in association with fragmentary shells of molluscs from the site near the village Khanpur. The charophyte species includes *chara rantzieni*, *chara rantizeni sivalensis* and ostracodes includes *Hemicypris.* Rage et al[4] first time recovered micro vertebrates assemblages of snakes, lizards and frogs from the two Siwalik sites viz 1. Ramnagar Member (Upper Miocene) includes *Acrochordus dehmi* (snakes), *Varanus* sp. (lizards) and ranidae and non –ranidae (frogs). 2. Labli Member (Upper Pliocene) includes anurans and colubroid snakes. The fauna comprises *Abudhabia* cf. *A. kabulense*, *Dilatomys piligrimi, Golunda kelleri, Golunda* sp., *Millardia* sp. indet., cf. *Mus flynni*, cf. *Parapelomys robertsi, Rhizomyides sivalensis* (rodents) and an insectivore-Soricidae gen. et. sp. indet. were reported from Labli Member of Upper Siwalik deposits of Jammu (Gupta and Prasad[5]). Following this, the microflora (charophyte) includes *Lychnothamnus barbatus, Hornichara maslovi and Boraginocarpus lakhanpalii* (angiospermae seed) and microfauna (ostracodes) includes *Hemicyprismegalops, H. pyxidata, Candona lacteal, Sclerocypris* ? sp.indet., *Cypridopsis* sp. indet were recovered from the two fossiliferrous yielding mudstone sites very near to village Barakhetar and Uttarbehani by Bhatia et al[6]. Prasad et al[7] reported first time a complete left mandibular bearing M1-M3 along with roots specimen of *Golunda* (*Golunda kelleri*) from the mudstones immediately below the volcanic ash beds exposed near Barakhetar village.

After a gap of 3 years, Bhandari and Kundal[8] collected sixteen species of ostracodes includes *Zonocypris barakhetarensis* sp. nov., *Darwinula jammuensis* sp. nov., *Ilyocypris bradyi, Ilyocypris* sp., *Darwinula* sp., *Sclerocypris* ? sp. and *Potamocypris* sp., *Cypris subglobosa, Cypris* cf. *C. decaryi*, *Cypridopsis* sp.A,?*Cypridopsis* sp., *Candona* sp.A, *Candona* sp.B, *Hemicypris pyxidata, Stenocypris major,Stenocypris* sp.*Eucypris* sp.A, *Eucypris* sp.B, from the same fossils yielding sites (Barakhetar and Uttarbehani). Kundal[12] have been also recovered six species of green algae charophytes from the Nagrota Formation includes *Hornichara maslovi*, *Chara contraria*, *Chara rantzieni*, *Chara globularis globularis, Lychnothamnous breviovatus, Lamprothamnium populosum*, cf. *Lamprothamnium and* one taxaon of angiospermae seed *Boraginocarpus lakhanpalii.* Kundal and Prasad[9] recovered some specimens of fish teeth, rodent's molar, fragmentary jaws of lizards, mammalian phalanges and claws, and indet. fragmentary bones from the Nagrota Formation of Jammu Siwalik. Recently, Kundal[10] gave details of the micro biotic

composition of Nagrota Formation of the Upper Siwalik subgroup of Jammu. Very recently, Kundal[11] also described some Late Pliocene mollusks fauna recovered from the Nagrota Formation. The present study has been carried to builds up palaeocommunity structure and palaeoecology of the Upper Siwalik deposits of Jammu based on the microfossil collected from time to time by various workers and the author itself from the study area. The area under study is shown in figure-1.

Material and Methods

More or less, the following methodologies were used by the various workers in the past and the author itself to collect the microfossils/ micro vertebrates from Siwalik of Jammu: Samples of fossil ferrous mudstone (25 kg, 50kg, so on, depending upon the richness of microfossils) were collected from identified microfossils/micro vertebrates yielding sites., The collected sample from the field than transported to the maceration laboratory. In laboratory, the soft samples were screen-washed in running water with different sets of sieves (most preferred, 60 mesh ASTM) after immersing in water for an hour or so. On the other hand, relatively hard mudstone samples were treated with kerosene/ different chemicals for disintegration. The screen-washed residue so obtained by both methods of sample disintegration were then dried in the sunlight and sorted under the microscope for microfossils and micro vertebrates. The microfossils so obtained were cleaned by ultra – thin needle for photomicrography, identification, systematic study and interpretation.

Results and Discussion

Following microfossils/ micro vertebrates were collected by using aforesaid technique from from Late Pliocene Upper Siwalik deposits of Jammu by author which includes Cyprnid fishes-Gen. sp. indet., (Fishes); anurans (Frogs); Crocodilia, *Varanus* sp. (varanide), Lacertilia indet. (Lizards); *Acrochordus dehmi* (crochordidade) (Snakes); cf. *Mus flynni,* cf. *Parapelomys robertsi, Golunda kelleri, Golunda* sp., *Dilatomys piligrimi, Millardia* sp. indet., *Abudhabia* cf. *A. kabulense, Rhizomyides sivalensis,*cf. *Rattus, Mus* sp., cf. *Mus jacobsi, Dilatomys* sp., ?*Tatera pinjoricus,* ?*Cremnomys blanfordi* (Rodents); *Hemicypris, Hemicypris megalops, H. pyxidata, Candona lacteal, Sclerocypris* ? sp. indet., *Cypridopsis* sp. indet, *Cypris subglobosa, Cypris* cf. *C. decaryi, Cypridopsis* sp.A,? *Cypridopsis* sp. B, *Candona* sp.A, *Candona* sp.B, *Eucypris* sp.A, *Eucypris* sp.B, *Stenocypris major, Stenocypris* sp., *Zonocypris barakhetarensis* sp. nov., *Ilyocypris bradyi, Ilyocypris* sp., *Darwinula* sp., *Darwinula jammuensis* sp. nov., *Potamocypris* sp., (Ostracods); *Gastrocopta* sp., *Gyraulus* sp., *Viviparus* sp., *Viviparus bengalinsis, Bellamya celispirals* (Gastropods); *Lamellidens lewisi, Oxynaia* sp. indet. (Bivalves); *Hornichara maslovi, Chara contraria, Chara rantzieni, Chara rantzieni sivalensis, Chara globularis globularis, Lychnothamnous breviovatus, Lamprothamnium populosum,* cf. *Lamprothamnium, Lychnothamnus barbatus, (*Charophytes) and *Boraginocarpus lakhanpalii* (Aangiospermae seed).

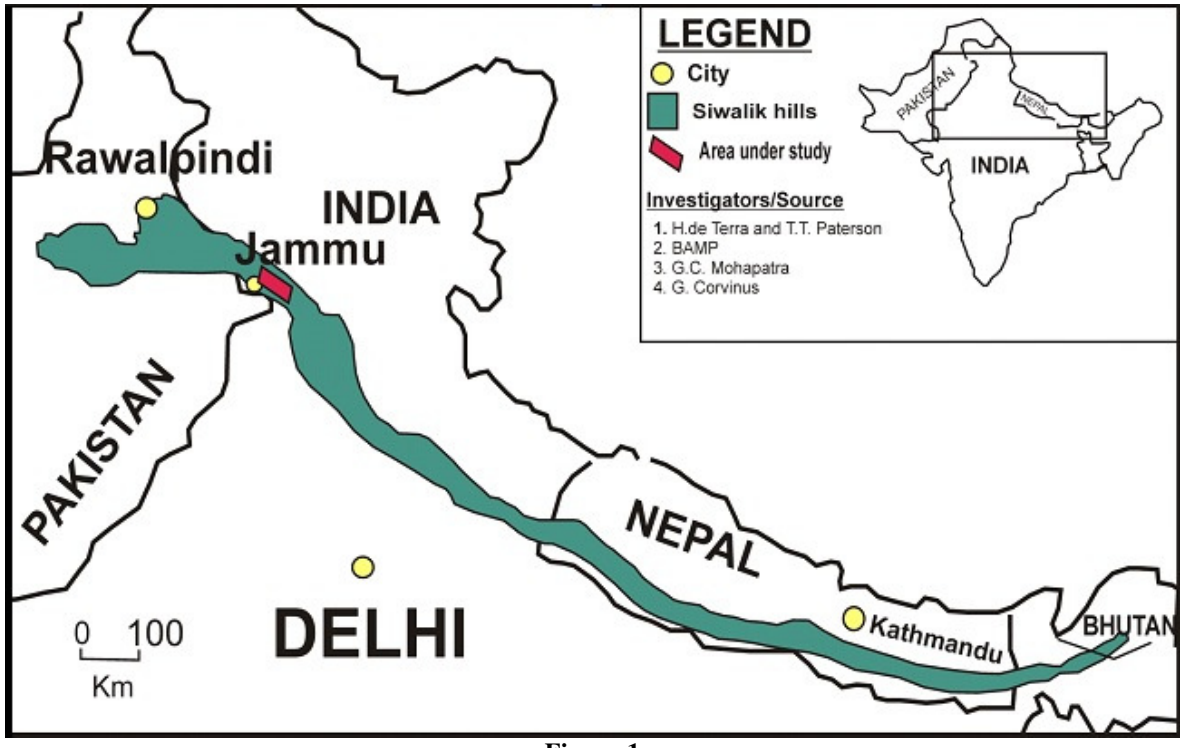

Figure-1
Range of Siwalik Hills (green) and area under study (pink)

Palaeoecology and Palaeocommunity structure analysis: Most of the species collected by author itself and other authors from time to time from the Late Pliocene deposits of Jammu Siwalik have closely related forms in the living taxas. Reconstruction of Palaeoecology of any area can be made by using the well known principle "Present is key to the past" (Huttonian Priniciple). Since the ecological distribution of taxon are controlled by biological, chemical and physical parameters which might have changed over time, so it is necessary to use all the taxon members of an assemblage or assemblage of different fossil to interpret the palaeoecology of the study area. In the present collection, three important fossil sources from which the palaeoecological inferences are derived are micro vertebrates (fishes, rodents) invertebrates (ostracodes, gastropods and bivalves) and plants (charophyte and angiosperm).

Micro vertebrate Evidence: The micro vertebrate faunal assemblages are generally confined to thin pockets of restricted lateral and vertical extent and represent localized environments. In other words, they depict either autochthonous or par autochthonous assemblages. In contrast, most of large vertebrate remains have been transported for a long distance before their burial. Thus the small vertebrate remains have proven to be highly useful in the reconstruction of past environments. The micro vertebrate fauna of the studied area is represented by micro mammals and fishes. Palaeoecological reconstruction based on micro mammals assemblages are quite reliable as they are found confined to beds of small lateral extent and deposited in a short period of time, and hence are quite useful in reconstructing palaeoenvironmental conditions. Rodents are used as indicators of climate due to their small sizes, sensitivity, usually have small homes and fast evolutinory history. As the most of taxa of rodents resembles with extant forms, the principle of actualism is used for palaeoecological inferences. The most successful living group among rodents is rats and mice which shows marked species diversity and are adopted themselves to many environmental conditions. After the death of rodents, the skeleton part preserved near to site of their small homes and used for reconstruction of palaeoclimate. In the present collection, the following taxa are reported by author from the study area includes ? *Ceremony blanfordi,* ?*Tatera pinjoricus*, *Millardia* sp., *Dilatomys* sp., cf. *Mus jacobsi, Mus* sp., *Golunda* sp., ?*Golunda kelleri*, *Mus flynni*, and cf. *Rattus.* The name of taxa and their habitats is given as under:

Taxa Name-Habitat, *Rattus-Rattus meltada* (extant species) living in rich vegetative plains, bush lands and thickets, field, Crops.-The various species of *rattus* occupied all terrestrial habitats from houses and rice fields to marshy rain forest to edges of grasslands. *Golunda-Golunda ellioti* (extant species) also living in field crops, densely vegetative plains, bushlands and predominantly grazers. *Cremnomys*-prefers thickets, wooded grasslands and non grazers. *Millardia-Millardia meltada*, the extant species prefers cultivated fields, shrubs, rocks and predominantly, Grazers. *Mus-Mus musculus and Mus booduga* (extant species) are non grazers, adapted ruderal environments. *Tatera-T. indica*, the extant species prefers to living on sandy plains and interdunal regions[13]. In Africa, *Tatera* prefers to live along the edges of alluvial flats, dry steppe and in thickets. Dilatomys-preferred grassy diet, etc. Reptiles, Lacertilian-lacertilian remains in the present collections points towards sandy tracts distal to aquatic bodies. Fishes, The fishes in the present collection belong to Cyprinid and represented by three teeth i.e. Morphotype I, Morphotype II and Morphotye III. Cyprinid-The extant members of Cyprinid fishes living in ponds, pools, standing water bodiesy and muddy, water, but some prefers sandy substrate with clean water bodies. In hilly terrain, the streams and rivulets (Himalayas) are the home of extant members of cyprinid family. Invertebrate Evidence, Ostracodes-Ostracodes have capacity to adapt every aquatic environment (marine, fresh, brakish water). They change themselves according to aquatic environmental conditions and are very useful for reconstruction of palaeoenvironment. The following ostracode fauna collected from the study includes *Potamocypris* sp., *Sclerocypris* ? sp., *Darwinula jammuensis* sp. nov., *Darwinula* sp., *Ilyocypris* sp., *Ilyocypris bradyi* Sars, *Zonocypris barakhetarensis* sp. nov., *Stenocypris* sp., *Stenocypris major* (Baird), *Hemicypris pyxidata* (Moniez), *Eucypris* sp.B, *Eucypris* sp.A, *Candona* sp.B, *Candona* sp.A,? *Cypridopsis* sp., *Cypridopsis* sp.A, *Cypris* cf. *C. decaryi* and *Cypris subglobosa* Sowerby. Taxa-Habitats, *Potamocypris* sp.-Shallow water lakes, streams with moderate vegetation, sometimes in association with a few candonids[27].

Hemicypris pyxidata-Dominant species in the present collection and prefers freshwater environment[15]. Earlier collected from Chilka lake (dried mudstone), ponds(fresh water) of Kutch[16,17], pond (alkaline) of Punjab[18], rice fields of Sri Lanka[19] and rock pools of Madurai[20]. *Hemicypris* prefers depth ranging from 1 to 3m and 25^0 C average temperatures and recovered from the ponds and lakes (freshwater) of Karnataka and Dharward. This species has capacity to tolerate fresh to brakish water permanent to semi-permanent water bodies[6].

Darwinula -Represented by *Darwinula* sp. and *Darwinula jammuensis* sp. nov. in the present collection. The species of *Darwinula* prefers freshwater conditions, but occasionally Mesohaline-Oligohalinelakes[15]. *Darwinula* sp. reported as *D. stevensoni* from the Chandigarh (Upper Siwalik beds) and Riwasa, Tehsil Bhiwani (limestone beds) by Bhatia and Khosla[21,22].

Stenocypris-Important sp. in the present collection, Occurred in shallow warm water lakes and ponds[23] and an active swimmer over muddy bottoms of standing water pools[24]. In association with *Ilyocypris bradyi* Sars, *Stenocypris* is found to occur infrequently in the rice fields of Kashmir valley[25]. *Stenocypris major* (Baird) occurred in rice fields, ponds and shallow water lakes.

Ilyocypris-Represented in the present collection by *Ilyocypris* sp. and *Ilyocypris bradyi* Sars. *Ilyocypris* sp. in habitat rice fields and small shallow water ponds, whereas *Ilyocypris bradyi*

abundantly prefers rice field environments. The presence of *Ilyocypris* indicates temporary or permanent running water or at least some current action in the water bodies[26,27]. It also indicates water turblence, in the marginal areas of water bodies by wind action[29]. The palaeoecological data pertaining to *I. bradyi* also indicates temporary and permanent running water conditions with rich vegetation[26,30,31].

Cypris subglobosa-found from rice fields[32], in habitat shallow water lakes and fresh water ponds, collected from Pleistocene deposits (Upper Karewa) of Kashmir and also threw light on its provenance and ontogeny[31].

Cypridopsis vidua-An active swimmer that prefers muddy bottoms. This species is prefers marginal shallow areas of permanent still freshwaters such as lakes, ponds, and ditches and running water with abundant vegetation[27,23]. From Kashmir Valley, Various taxa of ostracode of Quaternary age and their ecological conditions were discussed[23]. *Cypridopsis vidua* is also known to occur in fresh, slightly alkaline lakes rich in aquatic vegetation[33,23].

Candona sp.-Represented in the present collection by *Candona* sp. A and *Candona* sp. B. *Candona* sp. occurs in shallow water lakes (upto 6.20 meters depth) with rich vegetation. The depth of the *Candona* sp. is also extended upto 5.23 meters depth PH (7.10 to 900) and TDS (100 to 180 ppm) values[36]. Cold water stenothermic species represented by *Candona lacteal* and collected from terrace silts and lacustrine clays and silts[28]. The xtant species have also been collected frequently from rivers of England, Holland, and France[34]. This species was also collected from polyhaline waters[35]. *Candona lactea* not only occurs in Pleistocene freshwater, lacustrine sediments, but also in fresh, clear alkaline lakes of Kashmir valley[33,23].

Eucypris-Represented in the present collection by *Eucypris* sp. A and *Eucypris* sp. B. and known to occur in ponds, lakes, pools and swamps with abundant vegetation[37,38,39].

Zonocypris-Zonocypris barakhetarensis sp. nov. is the new species reported from the Upper Siwalik subgroup of Jammu reflects fresh shallow water lacustrine conditions.

Sclerocypris? sp.Found to occur in fined to coarse grained sediments (ferruginous) with little vegetation. fragile shells and tuberculate surface with marginal spines of *Sclerocypris dharwadensis* sp. reported from the freshwater lakes of Dharward, Karnataka which indicate sandy nature of substrate. Similar observations have also been made by Puri[40].

Mollscans: The living species of mollscans are known from aquatic (marine, freshwater, brackish water) and terrestrial environments. They found in dark gray to black mudstone and silty sandstones and are vagrant and bottom dwellers. Majority of the aquatic mollscans are preserved in situ whereas terrestrial mollscans preserved far from their habitat. Therefore aquatic moll scan should be better indicators of aquatic ecological conditions prevailing at any time. Two type of mollscans fauna reported in present collection i.e. Bivalves and Gastropods.

Bivalves Represented by *Lamellidens lewisi* and *Oxynaia* sp. indet. and have wide geographical and geological distribution. The extant forms are mostly marine and freshwater having range of adaptability up to6000meters.

Gastropods Represented by *Gastrocopta* sp., *Gyraulus* sp., *Viviparus* sp., *Viviparus bengalinsis*, and *Bellamya celispirals* in the present collection. Majority of taxas prefers low energy environment ranging from ponds, lakes to margin of slow flowing river, but generally avoid fast flowing waters.

Floral Evidence: Charaphytes: A considerable amount of information is available on the ecology of extant charophytes[41]. In contrast, little has been published on the palaeoecology of fossil forms with the exception of a few recent studies[42,43,45]. The ecology of extant and fossil forms is similar, so reference is made to extant ecology while interpreting the ecology of recovered fossil taxa. Charophytes form dense submerged vegetation in various kinds of continental waters. Their calcified reproductive organs (gyrogonites) represent autochthonous microfossils. Soulie-Marsche[43] demonstrated that depending upon the species charophytes can be used to identify deep and cold freshwater lakes, shallow freshwater lakes or marginal zones of deep lakes-tuffaceous deposits orignating in springs, temporary ponds with either fresh or brakish water, saline inland waters and also tropical lakes. In situ presence of charophyte flora has been shown to indicate supratidal-environment or emerged land. Charophytes cannot grow in acid or neutral environments and are not found in non-calcareous sediments. Generally they occur in alkaline water bodies, such as lakes and ponds with pH varying between 7.5to 8.0. They are superfically fixed on a substratum which may be mud, sand or silt-covered peat and sand[46]. The climate, hardness and salinity of water are the most obvious factors affecting their distribution[47]. In a number of freshwater environments, the sediment to a large extent is composed of charophyte remains and gastropod shells. This is a very common feature in the Deccan inter-trappean beds. Therefore, the presence of charophytes is taken as evidence for alkaline water bodies with little current action.

The present collection of charaphyte flora is represented as *Hornichara maslovi*, *Chara contraria*, *Chara rantzieni*, *Chara globularis globularis, Lychnothamnous breviovatus, Lamprothamnium populosum*, cf. *Lamprothamnium.* Besides one taxaon of angiospermae seed *Boraginocarpus lakhanpalii,* is also reported.

All the species of charophytes of present collection indicate freshwater, shallow lacustrine / pond environment except the species *Lamprothamnium populosum* and cf. *Lamprothamnium* which indicate saline conditions. *Lamprothamnium* is generally found in shallow waters up to a depth of 1-1.5m. *L. papulosum* and cf. *Lamprothamnium* are active and fructify in between 20-40% of salinity. Short period of low salinity down to 10% for

germination is also tolerated (Dubois[48]). This genus occurs neither in permanent freshwater nor in permanently high saline environments. This characterstic makes it particularly valuable as a marker for seasonal rainfall. But its occurrence in the freshwater fluvial / lacustrine sediments poses ecological questions. Soulie-Marsche[49] has demonstrated that abundance of gyrogonites suggests no transport or reworking during deposition. As transport during deposition would result in homogenous distribution, different distribution patterns or frequencies at different levels would indicate lack of reworking. In the present study, it is noticed that the distribution of charophyte taxa is not homogenous at different sites thus giving little credence to reworking.

From the palaeoecological analysis of recovered fauna and flora, it is apparent that there were two important palaeo communities- i. aquatic community, ii. terrestrial community. The aquatic community is mainly represented by lacustrine / paludal fauna and flora, whereas the land community is known by wooded grassland and bushland taxa. The palaeo community structure of the Late Pliocene Siwalik deposits is given in table

Table-1
Late Pliocene Palaeocommunity structure of the Upper Siwalik deposits of Jammu, JandK, India

Aquatic Community		**Terrestrial Community**	
Lake/pound and lake / bank community		Wooded grassland community	Bush land community
Flora: Charophytes *Hornichara maslovi* *Chara contraria* *Chara rantzieni* *Chara rantzieni sivalensis* *Chara globularis globularis,* *Lychnothamnous breviovatus,* *Lamprothamnium populosum* cf. *Lamprothamnium* *Lychnothamnus barbatus* Aangiospermae *Boraginocarpus lakhanpalii*	Fauna: Ostracods *Hemicypris* *Hemicypris megalops* sars *H. pyxidata* *Candona lactea* Baird *Sclerocypris* ? sp. indet. *Cypridopsis* sp. Indet *Cypris subglobosa* Sowerby *Cypris* cf. *C. decaryi* *Cypridopsis* sp.A ?*Cypridopsis* sp. *Candona* sp.A *Candona* sp.B *Eucypris* sp.A *Eucypris* sp.B *Stenocypris major* (Baird) *Stenocypris* sp. *Zonocypris barakhetarensis* sp. nov. *Ilyocypris bradyi* Sars *Ilyocypris* sp. *Darwinula* sp. *Darwinula jammuensis* sp. nov. *Potamocypris* sp Gastropods *Gastrocopta* sp. *Gyraulus* sp. *Viviparus* sp. *Viviparus bengalinsis* *Bellamya celispirals* Bivalves *Lamellidens lewisi* *Oxynaia* sp. indet Fishes Cyprnide fishes-Gen. sp. Indet.	Fauna: Mammals *Dilatomys* sp. ?*Cremnomys blanfordi*	Fauna: Lizards *Varanus* sp. (varanide) Lacertilia indet. Snakes *Acrochordus dehmi* (Acrochordidade) Rodents cf. *Mus flynni* cf. *Parapelomys robertsi* *Golunda kelleri* *Golunda* sp. *Dilatomys piligrimi* *Millardia* sp. indet. *Abudhabia* cf. *A. kabulense* *Rhizomyides sivalensis* cf. *Rattus* *Mus* sp. cf. *Mus jacobsi* ?*Tatera pinjoricus blanfordi*

Conclusion

The collected fauna and flora from Late Pliocene deposits of Jammu Siwalik belongs to two important dominated palaeocommunities i.e. terrestrial palaeocommunity and aquatic palaeocommunity and these palaeocommunities favor a shallow water lacustrine / paludal environment. The presence of terrestrial elements (rodents, lizards, etc.) in a predominantly lacustrine assemblage is not unusual, as animals living on the water edge can easily be brought into the basin by run off after their death there is hardly any evidence to show that the remains of terrestrial animals were transported over a long distance before their incorporation into the lacustrine assemblage. The rodent teeth and bones show no rounding of edges and breakage of cusps on the teeth. In fact, the teeth have very sharp cusps. It is thus concluded that permanent, shallow water lacustrine /paludal basins existed in the investigated area during the Late Pliocene times.

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