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Preliminary study of fossil freshwater molluscs from the Plio-Pleistocene Kathmandu Basin sediments, central Nepal

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ABSTRACT

Fossils of freshwater mollusca from the fluvio-lacustrine sediments of the Kathmandu Basin are collected from localities in the upper part of the Lukundol Formation, of Late Pliocene to Early Pleistocene age, and the Gokarna Formation, of Late Pleistocene age. Despite the temporal differences of the two localities, the dominant molluscan species in each locality are similar. The fossil molluscan fauna in the older Lukundol Formation is entirely composed of prosobranch gastropod shells belonging to the genus *Bellamya* and opercula of the genus *Digoniostoma*. The fauna in the younger Gokarna Formation includes similar prosobranch species with addition of one prosobranch species, along with three pulmonate gastropods, an unidentified terrestrial gastropod and a bivalve species. The additional prosobranch species belong to the genus *Gabbia*, and the pulmonate gastropods are of the genera *Lymnaea*, *Gyraulus*, and *Planorbis*. The only bivalve species belong to the genus *Pisidium*.

In the Lukundol Formation, fossil molluscan shells are abundant but poor in number of species and the assemblage is dominated by lacustrine taxa preferring permanent lentic water body of shallow depth. Conversely, in the Gokarna Formation, species diversity is comparatively higher, with inhabitant of the shallow lacustrine to marginal less stable habitats. The fossil molluscan faunal composition is more similar to the recent fauna that inhabits the warmer southern Terai region of Nepal.

INTRODUCTION

The Kathmandu Valley is an intermontane basin in the Lesser Himalaya of Nepal. The valley is filled with fluvial, lacustrine and delta deposits considered to have been resulted from damming in the southern part of the valley. Several investigations have been carried out to determine the sub-surface geology and history of the sedimentary basin (Moribayashi and Maruo 1980; Motojima et al. 1980, Yoshida and Igarashi 1984). Similarly, reports have been published on the vertebrate fossils (West and Munthe 1981; Dongol, 1985) and pollen analysis (Vishnu-Mittre and Sharma 1984; Yoshida and Igarashi 1984) from the Kathmandu Basin to make clear their age and palaeoclimatic condition. The age of the Kathmandu palaeolake sediments is considered to range from Middle Pliocene to the Late Pleistocene in age as determined from palaeomangnetic measurement (Yoshida and Gautam 1988), radio carbon dating (Yoshida and Igarashi 1984) and the mammalian fauna (West and Munthe 1981; Dongol 1985).

Occurrences of molluscan fossils from the Kathmandu Basin sediment have been mentioned (Sah et al. 1991), but have not been studied in detail. Although the present investigation is preliminary, it is the first record of the Quaternary freshwater molluscan fossils from Nepal. It shows some interesting environmental perspective of the Palaeo-Kathmandu Lake by way of molluscan fauna. The taxonomy presented and conclusion reached in this paper might change following a more comprehensive study.

GEOLOGY

Geological and geomorphological investigations have divided the fluvio-lacustrine sediments into various formations and geomorphic surfaces (Yamanaka 1982; Yoshida and Igarashi 1984; Dongol 1985). For the present study, classification presented by Igarashi et al. (1988) is followed. They have divided the basin fill deposits into three groups with seven formations.

The older stage deposits

These are named as Lukundol Formation and consist of lacustrine sediments. The formation is mainly composed of siltstone alternation and intercalation of peat and coal lenses. The age of this older deposit is considered to be Late Pliocene to Middle Pleistocene based on palaeomagnetic measurement (Yoshida and Igarashi 1984; Yoshida and Gautam 1988) and on the vertebrate fossils (West and Munthe 1981; Tuladhar 1982; Dongol 1985). The sediments of this formation are mainly exposed in the southern part of the valley.

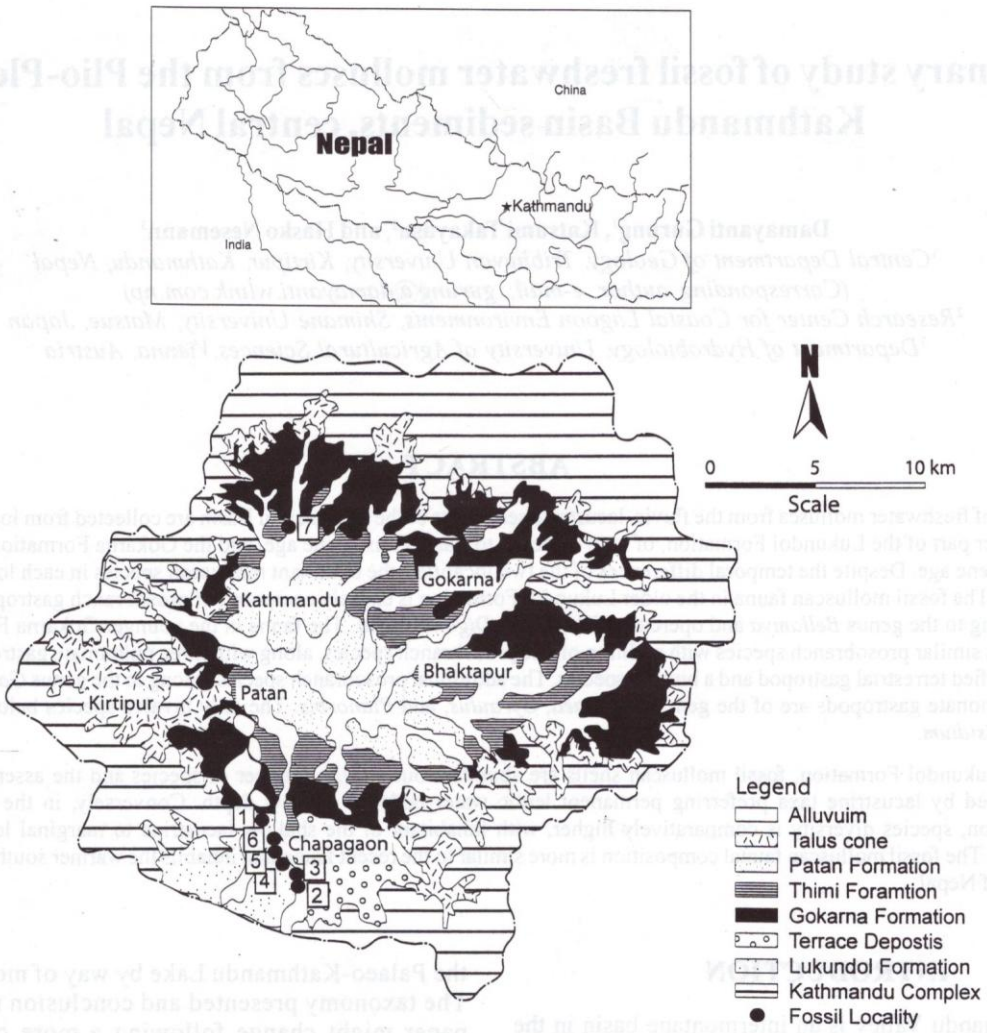

Fig. 1: Simplified geologic map of the Kathmandu Valley with molluscan fossil locality

The middle stage deposits

They are mostly terrace deposits and divided into three formations - Pyanggaon, Chapagaon and Boregaon terrace deposits, in ascending order. These terrace deposits are assumed to be younger than Middle Pleistocene in age and unconformably overlies the Lukundol Formation. The deposits are mainly composed of pebble to cobble size, subrounded to rounded fluvial gravel. The sediments of these formations are also mainly distributed in the southern part of the basin.

The younger stage deposits

They are composed of fluvio-lacustrine deposits and are divided into Gokarna, Thimi and Patan formations, in ascending order. The younger stage deposits are estimated to range from 40,000 to 11,000 yr. B. P., from radiocarbon dating (Yoshida and Igarashi 1984). However, they may probably be older. These deposits consist of laminated arkosic sand, silt, clay and grey to dark brown coloured peat. These formations are distributed in the central and northern part of the valley.

MOLLUSCAN FOSSIL LOCALITY

Lukundol Formation Locality

There are six molluscan fossil localities from the Lukundol Formation, of the older stage deposits, in the Southern part of the Kathmandu Valley (Fig. 1). The fossil localities are on the left bank of Nakhu Khola, below Chapagaon village (Fig. 1- Loc. 2, 3, 4, 5, 6), and further downstream, west of the Bungamti village, along the Bungamati-Tauthali footpath (Fig.1- Loc.1). The fossil-bearing bed lies in the upper part of this formation (Fig. 2). In Loc. 1, 2, and 3, fossil shells of *Bellamya* sp. (Fig. 3-a) with some *Digoniostoma* sp. (Fig. 3-c) opercula are embedded in grey to dark brown mudstone, 30 to 40 cm thick. The shells are large in size (4 to 4.5 cm), abundant but are crushed and compacted, and yet, shell surface sculptures are well preserved. The opercula are small (3 to 4 mm), calcareous and well preserved. In Loc. 4, 5, and 6, *Digoniostoma* sp. opercula occurred in concentration in dark grey mudstone, 15 to 20 cm thick, forming thin layers with rare *Bellamya* sp. shells.

Gokarna Formation Locality

There is only one fossil locality, Loc. 7, in the Gokarna Formation, of the younger stage deposits, near the village of Manamaiju, along the Balaju-Dharamthali road, on the right bank of the Mahadev Khola (Fig. 1). The fossil-bearing bed lies in the upper part of this formation (Fig. 2). Fossils are less abundant in this locality but have various species. The molluscan fossils are found in dark grey to black mudstone, about 100 cm thick, intercalated with 3 to 5 cm thick, light grey diatomaceous clay in the upper part. In the mudstone bed, large shelled *Bellamya* sp. and calcareous opercula of *Digoniostoma* sp. are found scattered. The shells in the Gokarna Formation are not compacted and concentrated as in the Lukundol Formation localities. The shells are well preserved and complete. Toward the upper part of the mudstone beds, small gastropod and bivalve are present and there is some intercalation of thin beds of opercula, ca. 1 to 2 cm thick. The small gastropods include *Gabbia* sp. (Fig. 3-b), *Lymnaea* sp. (Fig. 3-f), *Gyraulus* sp. (Fig. 3-e), *Planorbis* sp. (Fig. 3-d), unidentified terrestrial gastropods (Fig. 3-g), and a bivalve species *Pisidium* sp. (Fig. 3-h).

MOLLUSCAN FOSSIL OCCURRENCES

The large fossil shells from both the Lukundol and Gokarna Formations are compared to be similar, and based on shell morphology it is identified to belong to the genus *Bellamya*. The fossil opercula from all fossil localities are also nearly similar in size and shape. They are white,

calcareous, have concentric growth lines with paucispiral nucleus placed slightly sub-centrally. Such calcareous opercula that are as large as the aperture are found in species belonging to the family Bithyniidae. The family Bithyniidae includes several genera, namely *Bithynia*, *Digoniostoma*, *Sataria* and *Gabbia*. Because of its size, shape and growth line patterns the opercula are identified as belonging to the genus *Digoniostoma*. The present identification is carried out on the characteristics of the opercula since the shells are yet to be found associated with it.

Based on the molluscan shell parts, the fossil beds can be divided into two types, A. "*Bellamya* shell bed" and B. "Opercula bed".

Both types are found in the Lukundol and Gokarna Formations. At all the observed exposures, the "Opercula bed" is inferred to be above the "*Bellamya* shell bed" at present.

***Bellamya* shell bed**

It is here termed as the bed that is comprised almost entirely of *Bellamya* sp. shells with some opercula of *Digoniostoma* sp. (Fig. 4-A, B, C). In the southern Lukundol Formation localities (Loc.1-3), shells of *Bellamya* sp. and some opercula of the genus *Digoniostoma* sp., form calcareous shell bed in dark grey mudstone (Fig. 4-A). However, in the Gokarna Formation (Fig.1 - Loc.7), the "*Bellamya* shell bed" does not form calcareous shell bed, but rather a mudstone bed with scattered shells of *Bellamya* sp. and some opercula of the genus *Digoniostoma* sp. (Fig. 4-C). In Loc. 2, there are two shell beds, about 30 to 40 cm thick, interbedded in the lower part of the dark grey mudstone bed. Similar bed is exposed 200 m further downstream at fossil Loc. 3. More shell beds are found further downstream, west of the Bungamati village, along the Bungamati-Taulthali footpath, in Loc.1 (Fig. 4-B). These shell beds are from 20 to 40 cm thick. The Loc. 7 is only one

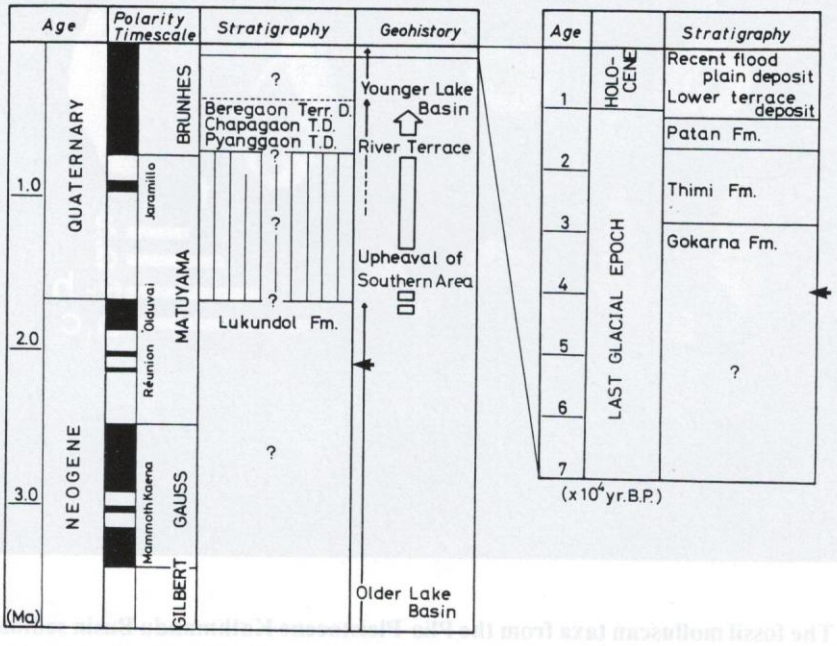

Fig. 2: The stratigraphic position of the fossil horizons (shown by thick arows) in the Lukundol and Gokarna formations

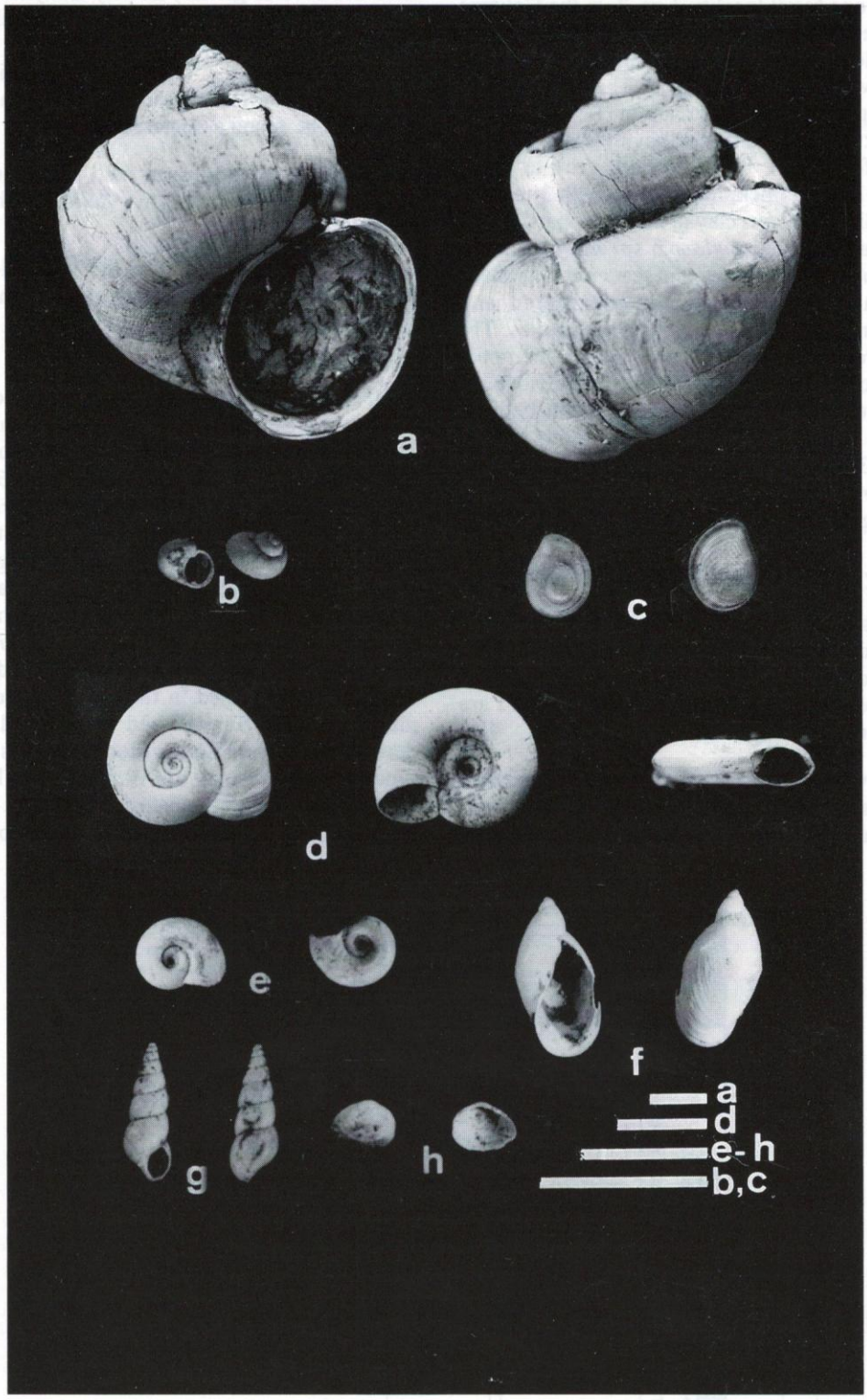

Fig. 3: The fossil molluscan taxa from the Plio-Pleistocene Kathmandu Basin sediments. a. *Bellamya* sp.; b. *Gabbia* sp.; c. Opercula of *Digoniostoma* sp.; d. *Planorbis* sp.; e. *Gyraulus* sp.; f. *Lymnaea* sp.; g. terrestrial pulmonate (?); h. *Pisidium* sp. Scale bar is 5 mm.

"*Bellamya* shells bed" in the Gokarna Formation (Fig. 4-C). The shells and opercula are found scattered within dark grey mudstone bed, ca. 100 cm thick, which are not compacted and concentrated as in the southern ones, but are well preserved complete shells.

Although shell preservation is different, the shells in "*Bellamya* shell bed" of the two formations are similar in morphology. The shells are of different growth sizes, no size sorting is evident, and no indications of preferred shell orientation. The fossil shells are found only in the fine mudstone bed with faint lamination.

Opercula bed

It is composed of concentrated opercula of *Digoniostoma* sp. with rare shells of *Bellamya* sp. (Fig. 5-A and 5-B). It consist of small oval white calcareous opercula, 3 mm x 2 mm, lying parallel to the bedding plane in grey mudstone, forming thin, about 1 to 2 cm, laminae. The grey mudstone beds of these laminas are about 10 to 20 cm thick, forming thin parting within.

The opercula in the "Opercula bed" of the two formations are similar in shape, size, and degree of preservation. In both formations, they show slight size sorting, as size of the opercula ranges from mostly 3 mm x 2 mm to 4 mm x 3 mm, and all are orientated with flat surface parallel to the bedding plane. They are well preserved with distinct growth lines. Sorting may have been due to current action.

In the southern Lukundol Formation, the "Opercula bed" is approximately 5 m above the "*Bellamya* shell bed" (Fig. 5-A). In the Gokarna Formation, it is approximately 1 m above the "*Bellamya* shell bed" (Fig. 5-B).

TAXONOMY OF THE FOSSIL MOLLUSCAN FAUNA

The taxonomic conclusion reached here is based on a preliminary comparative study only, therefore, in later more comprehensive study the result may change. It is found that these Late Pliocene to Late Pleistocene molluscan species belong to genera that recently occur in the Nepalese freshwater fauna (Table 1). However, at the specific level most taxa are not found to be similar to the living ones. Some taxonomic notes are mentioned based on comparison of shell morphology to the recent ones.

The fossil *Bellamya* sp. differs distinctly by its shell size and shape from the living Indian subcontinent species of *Bellamya bengalensis* (Lamarck 1822) and *Bellamya dissimilis* (O.F. Müller 1774). It has no significant similarities with other forms of this genus found in Nepal and the Indian subcontinent. Therefore, *Bellamya* sp. (Fig. 3-a) can be regarded as a fossil endemic species of the Palaeo-Kathmandu Lake.

Among the fossil Bithyniidae, represented by large opercula with central to subcentral nucleus (Fig. 3-c) and few small shells. The large opercula resemble that of the living species of *Digoniostoma cerameopoma* (Benson 1830) and *D. pulchella* (Benson, 1836). Both presently inhabit warm stagnant or slowly running waters of the Gangetic plain and the Nepalese Terai with isolated records up to an altitude of 880 meters above mean sea level in Pokhara Valley. The small fossil Bithyniidae (Fig. 3-b), represented by shells only, may represent juvenile shells of *Gabbia* sp. In the midmountain region of the Nepal Himalaya a common and widespread prosobranch is *Gabbia orcula* (Frauenfeld 1862).

The fossil Planorbidae is represented with at least two species, which are preliminarily placed into the genera *Gyraulus* and *Planorbis*. The taxonomic value of the various living forms is uncertain and needs verification. The fossil *Gyraulus* sp. (Fig. 3-e) is most similar to the living *Gyraulus*

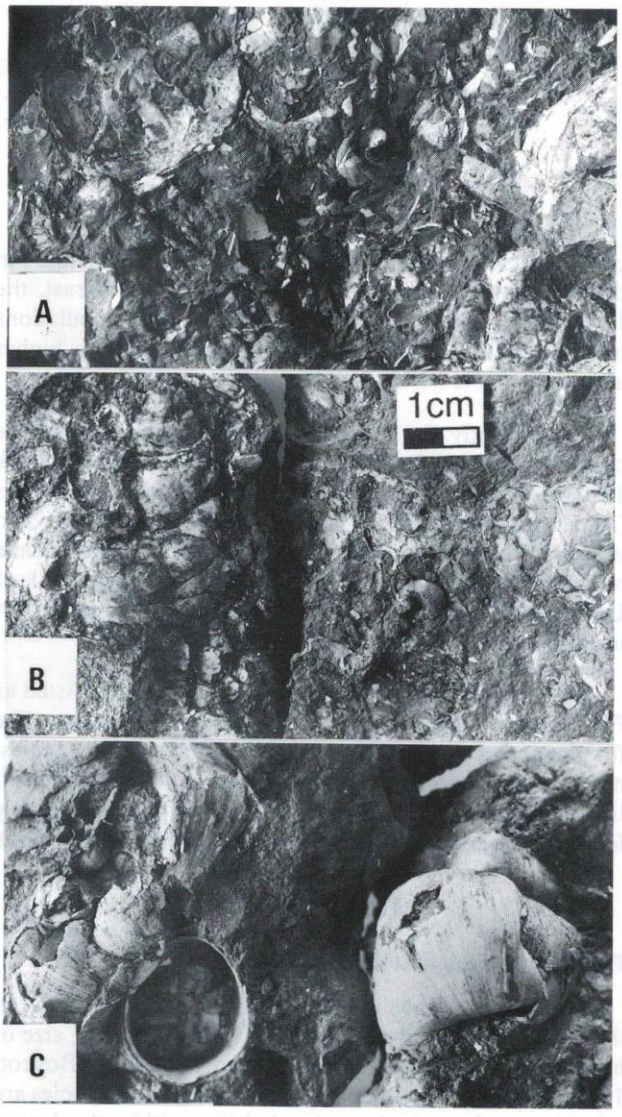

Fig. 4: The "*Bellamya* shell bed". A. Chapagaon Locality of the Lukundol Formation. B. Bungamati Locality of the Lukundol Formation. C. Manamaiju Locality of the Gokarna Formation.

Table 1: List of molluscan taxa identified from the Plio-Pleistocene Kathmandu Basin sediments

Class Gastropoda
Subclass Prosobranchia
Family Viviparidae
Genus *Bellamya*
Bellamya sp.
Family Bithyniidae
Genus *Digoniostoma*
Digoniostoma sp.
Genus *Gabbia*
Gabbia sp.
Subclass Pulmonata
Family Lymnaeidae
Genus *Lymnaea*
Lymnaea sp.
Family Planorbidae
Genus *Gyraulus*
Gyraulus sp.
Genus *Planorbis*
Planorbis sp.
Class Bivalvia
Family Pisidiidae
Genus *Pisidium*
Pisidium sp.

convexiusculus (Hutton, 1849), which occurs abundantly in the Bagmati and Sapta Kosi watersheds. In contrast, the fossil *Planorbis* sp. (Fig. 3-d) resembles living populations of the Nepalese Terai, which are not yet found in higher altitudes.

Interestingly the fossil Lymnaeidae (Fig. 3-f) can be certainly added to the living *Lymnaea acumminata* (Lamarck 1822) (=*Radix acumminata*). This basommatophore species (Annandale and Rao 1925) prefers shallow stagnant and warm waters of the Terai. Occasionally *L. acumminata* occurs in some restricted inner Himalayan valleys (Bhimtal, Kumaon hills of Uttaranchal province; Dhulikhel, Dhobi Khola, Kavre district in Nepal) up to 1900 meters above mean sea level.

The classification of the fossil bivalve species, listed as *Pisidium* sp. (Fig. 3-h), still needs further verification. The fossils species maybe represented by more than one species, however, it can not be ascertain at present. It differs from all living species of the family Pisidiidae, which were recently found in Himalayan region (Prashad 1925; Nesemann et al. 2001).

DISCUSSION

Palaeoenvironmental Implication

Many studies have indicated strong correlation between the abundance and diversity of freshwater molluscs, size of habitat and dissolved salt or water quality variables (Boycott 1936; Dillion 2000; Russell-Hunter 1978). Most species are inhabitant of particular microhabitat within the larger environment; however, some can tolerate a range of a particular environment. The present distribution of molluscan fauna of the Kathmandu Valley or of the surrounding areas will be very important for inferring for the fossil species.

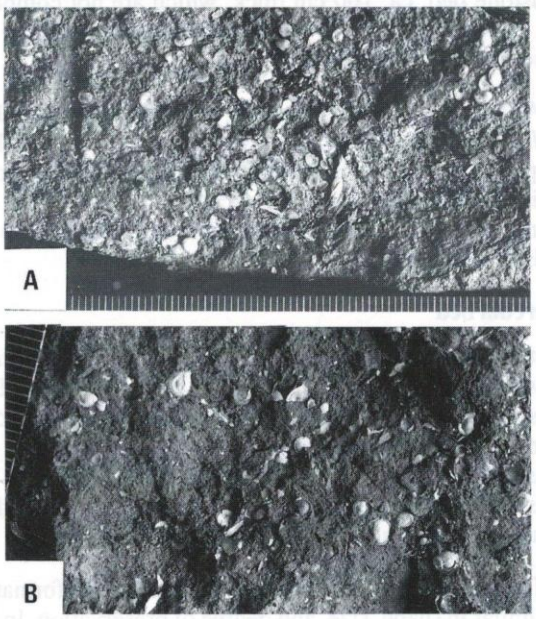

Fig. 5: The "Opercula bed". A. Chapagaon Locality of the Lukundol Formation and B. Manamaiju Locality of the Gokarna Formation.

There are few but valuable reports on the molluscan fauna of the Indian subcontinent (Subba Rao 1989) and Nepal (Subba and Ghosh 2000; Nesemann et al. 2001). Palaeoenvironmnetal interpretation of the molluscan assemblage is based on the assumption that the fossil taxa had similar environmental requirement as those of living ones. Based on the habitat preference of recent molluscan species a palaeoenvironment interpretation is attempted.

The dominant species in both formations, in the "*Bellamya* shell bed", is a species belonging to the genus *Bellamya*, a prosobranch belonging to family Viviparidae. Freshwater prosobranch are animals of the more permanent water body, generally found abundantly in low energy environment such as margins of slow flowing rivers, shallow ponds and lakes. It may have been the inhabitant of shallow waters of the Palaeo-Kathmandu Lake. The abundant occurrences of the shell may probably indicate a permanent expanse of shallow peripheral zone of the lake proper, offshore to marsh. Their preservation also indicates very little transportation. In the Lukundol Formation, the shells are crushed by post-depositional process of compaction but in spite of the fragile shell their surface is well preserved, and they are not size sorted. All these strongly indicate that the molluscan bearing beds were deposited *in situ*, in low energy environment with very little influence of running water.

In the Gokarna Formation, other species, alongside the above-mentioned species, start to become dominant above the "*Bellamya* shell bed". These are prosobranch species

Gabbia sp. (Family- Bithyniidae), aquatic pulmonates belonging to the genera *Lymnaea* (Family- Lymnaeidae), *Planorbis* and *Gyraulus* (Family- Planorbidae); and the only bivalve belong to the genus *Pisidium* (Family- Pisidiidae), and unidentified terrestrial gastropods. The freshwater pulmonates are mostly animals of marginal littoral water. The planorbid species, *Planorbis* sp. and *Gyraulus* sp., are littoral animal and are usually not found in deep water or rapidly running water. These species are commonly found on fine sediments, with rich decaying organic matter and weak current with abundant algae and soft aquatic vegetation (Germain 1923; Dillon 2000). They also have the ability to live under unfavourable condition, where water body partially dry up during dry season. The other pulmonat, *Lymnaea*, generally inhabit slow flowing water, marshes to shallow stagnant water bodies (Rao 1929). The only bivalve species *Pisidium* sp. is most similar to species which commonly inhabit muddy stream margins of pond and lakes (Prashad 1925; Rao 1928). Therefore, the molluscan faunal assemblage in the Gokarna Formation may indicate a marshy lake margin which may partially dry up seasonally.

"Opercula bed" seems to have formed by particular taphonomical condition rather than by an ecological one. The concentration of the calcareous opercula of *Digoniostoma* sp. is most probably on account of transportation from it marginal environment by current action. The living species of this genus are found in shallow pools, ponds and sluggish streams with dense aquatic vegetation (Rao 1928). The abundant of opercula indicates the species may have been plentiful in the surrounding marginal area of the lake, however, shell itself has not been found. The occurrence of the "Opercula bed" in fine mudstone in thin layers indicate sedimentation in quite water condition, probably in the deeper part of the lake.

In the older Lukundol Formation, fossil molluscan assemblage indicates a permanent shallow lake environment, during the deposition of the "*Bellamya* shell bed". In the upper Gokarna Formation "Bellamya shell bed" is gradually replaced by fossil species that inhabit marshes and tolerate partially drying up, indicating shallowing up of lake water level.

Palaeobiogeographic Implications

The fossil molluscan fauna of the Kathmandu Basin shows some interesting aspects, which are, 1) low species count, 2) presence of two similar species in two formations separated by long interval of time, 3) dominance of shallow water species, and 4) dominance of fauna of the warmer climatic condition.

The extent of the fluvio-lacustrine sediments indicates the Palaeo-Kathmandu Lake to be a large one. Such large lake standing for a considerable age (Late Pliocene to Late Pleistocene) generally hold high diversity of fauna and flora (Boss 1978). The present investigation found three prosobrachs, three aquatic pulmonats (Basommatophora), one probably terrestrial pulmonate and one bivalve taxa. The Lukundol Formation has been correlated to the Pliocene to Pleistocene Karewa Beds of Kashmir Basin and the Upper Siwalik (West and Munthe 1981; Yoshida and Igarashi 1984). The Karewa Beds of Kashmir has much higher diversity of molluscan fossils (Prashad 1937; Bhatia 1974) with more than 18 taxa of aquatic, semi-aquatic and terrestrial ones. Similarly, the Upper Siwalik molluscan fauna of Nepal also has high number of species (Gurung 1998). Freshwater molluscs disperse by passive means of dispersal to colonize different water bodies, such as transportation by fish, by migration of aquatic animals, like water birds (Rees 1965; van Damme 1984). Consequently, most large permanent lakes increase their molluscan faunal diversity with age (Boycott 1936). This trend, though present, is weak in the case of the Palaeo-Kathmandu Lake. This low diversity of molluscan fauna in the Palaeo-Kathmandu Lake may probably be due to the special geochemical regime of the lake, such as low dissolved salt or water quality variables, rather than by transportation isolation.

It is interesting to note that the molluscan fossil fauna of both, Lukundol and Gokarna, formations share the same species, *Bellamya* sp., despite being separated by a long time interval. The shells of *Bellamya* sp., of both formations, have similar shell morphology and probably inhabited similar warmer environment. The sedimentological studies of the Kathmandu Basin have indicated the existence of the lake during Late Pliocene to Middle Pleistocene (Lukundol Formation) and during the Last Glacial age (Gokarna Formation), with terrace deposit during Middle Pleistocene (Yoshida and Igarashi 1984; Igarashi et al. 1988). However, the continuous prevalence of the same species in the two formations indicates the continuous presence of their habitat, a shallow lake. Therefore, it can be assume that between the deposition of the Lukundol and Gokarna formations the lake never completely disappear, even during many lake outbursts. It can also imply that the two formations may not be separated by such long interval of time as indicated by previous authors (Yoshida and Igarashi 1984; Yoshida and Gautam 1988).

The fossil molluscan fauna of the Palaeo-Kathmandu Lake suggest a warmer condition, as it is dominated by taxa that are most similar to the one that at present inhabit the warmer Terai region of Nepal. Only *Gabbia* sp., *Gyraulus* sp. and *Pisidium* sp. have species that have wider distribution from the warmer Terai to the higher latitude region of Nepal.

CONCLUSIONS

The freshwater molluscan fossils from the Kathmandu Basin sediments are found to include prosobranchs belonging to the genus *Bellamya* sp. (Family- Viviparidae), *Digoniostoma* sp., *Gabbia* sp. (Family- Bithyniidae); pulmonats belonging to *Lymnaea* sp. (Family- Lymnaeidae), *Planorbis* sp. and *Gyraulus* sp. (Family- Planorbidae); and the bivalve belong to the genus *Pisidium* (Order- Veneroidea, Family- Pisidiidae).

Based on the molluscan shell parts, the fossil beds have been divided into two types, A. "*Bellamya* shell bed" and B. "Opercula bed". Both types are found within the two fossil-bearing formations. At all the observed exposures, the "Opercula bed" is inferred to be above the "*Bellamya* shell bed".

The molluscan fossils of "Bellamya shell bed", from the Lukundol Formation suggest shallow peripheral zone of the lake proper, offshore to marsh. Their preservation also indicates very little transportation. However, the formation of the "Opercula bed" may probably have been by current action. During the deposition of the Gokarna Formation molluscan fauna becomes more diverse with addition of species that inhabit marshy lake margin which may partially dry up seasonally.

The fossil molluscan fauna of the Kathmandu Basin show, 1) low species count, 2) presence of similar taxa in two formations separated by long interval of time, 3) dominance of shallow water species, and 4) dominance of fauna of the warmer climatic condition. It is speculated that the low diversity of the Palaeo-Kathmandu Lake may be related to low dissolved salt or water quality variables, rather than by transportation isolation. The presence of same dominant species in the Lukundol and Gokarna formations suggests that these formations may not be separated by along time interval. The predominance of shallow benthos molluscan fauna in the molluscan assemblages indicates that the lake was with large expanse of marshes and shallow water environment.

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