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Freshwater molluscs from the Late Neogene Siwalik Group, Surai Khola, western Nepal

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ABSTRACT

The fossil freshwater molluscs collected from the Siwalik (Churia) Group, along the Surai Khola section, western Nepal, are systematically studied. The molluscan fauna is represented by gastropods belonging to family Viviparidae, Ampullariidae, Bithyniidae, Thiaridae, and bivalves belonging to family Unionidae, Corbiculidae and Pisidiidae. Four new species *Angulyagra shiddarthai, Brotia dobataensis*, *Paludomus suraiensis* and *Parreysia chureii* are described in this paper.

INTRODUCTION

The Himalayan orogeny resulted in the formation of one of the largest terrestrial foreland basins with major river systems during the Neogene. The thick fluvial sediments shaded from the uplifting Himalaya are represented by the Neogene Siwalik (Churia) Group, forming the low southern foothills along the whole length of the Himalayan range. The tectonic evolution of the Himalaya brought about changes in the environments of the region with the related change in the flora and fauna of the surrounding region. Thus, fossils incorporated within these deposits have significance as an indicator of the prevailing environment during the deposition.

In the Siwalik sediments of Nepal, freshwater molluscan fossils are found more commonly than vertebrate fossils. However, studies related to molluscan fossils are very few. Most of the palaeontological studies are focused on vertebrate fossils (West et al., 1978; Munthe, 1983; Conroy et al., 1985; West et al., 1991; Corvinus, 1993; Corvinus, 1994; Corvinus and Nanda, 1994). The first published report on the molluscs of Nepal Siwaliks was from Surai Khola area by West et al. (1975), where no systematic description is given.

Taxonomic study forms the foundation for palaeoecological, palaeobiogeographic, and stratigraphic interpretations. In this respect, systematic studies of the molluscan fossils of the Nepal Siwaliks have been carried out in the Arung-Binai Khola area by Takayasu et al. (1995) and Gurung et al. (1997). It is hoped that the present systematic study of molluscan fossils from the Surai Khola area will contribute further to their study.

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GEOLOGICAL SETTING

The study area (Surai Khola section) lies about 250 km southwest of Kathmandu (Fig.1). The lithostratigraphy for the Surai Khola area was proposed by Corvinus (1988) and recently Dhital et al. (1995) updated it with slight modifications. The modified lithostratigraphy is followed here. In the study area, the Siwalik Group is separated from the pre-Tertiary older rocks in the north by the Main Boundary Thrust (MBT) and from the younger post-Tertiary sediments in the south by the Main Frontal Thrust (MFT). Beside that several nearly east-west trending thrusts divide the Siwalik Group into various belts (Fig. 2). The fossil specimens described in the present study are collected from the southern most belt (Fig. 3).

The Siwalik Group in the study area is subdivided into five formations, namely the Bankas, Chor Khola, Surai Khola, Dobata and Dhan Khola formations, in ascending order. The division is made on the basis of the grain size, bed thickness, sedimentary structure and the proportion of detrital mica, quartz and feldspar (Dhital et al., 1995). The

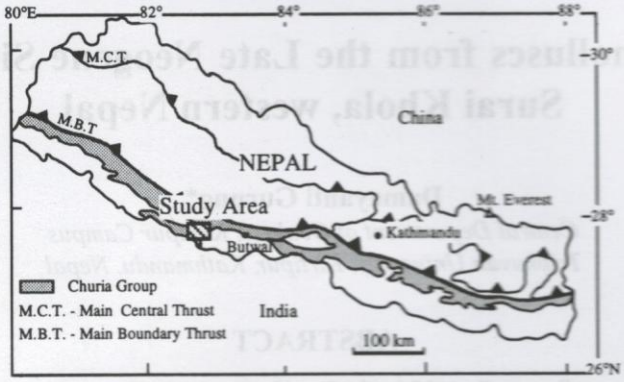


Fig. 1: Location map of the study area..

age given is based on the palaeomagnetic polarity measured by Appel et al. (1991) with polarity sequence correlated to the timescale of Cande and Kent (1995) (Table 1).

Bankas Formation

It is mainly composed of nearly equal amount of medium to very fine grained sandstone, and variegated and bioturbated siltstone, with rare shale and calcertes. The contact with the overlying Chor Khola Formation is gradational. Molluscan fossil was not found in this formation.

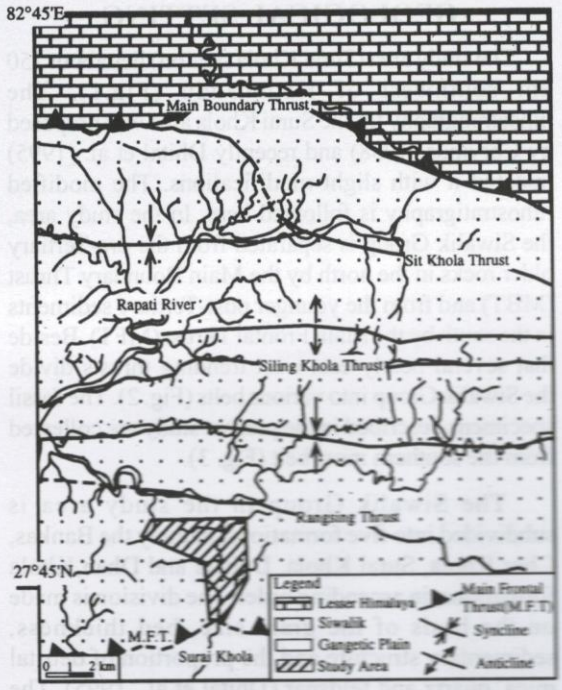


Fig. 2: The Siwalik Group and the main geological structures in the Suria Khola area.

Chor Khola Formation

This formation is divided into the lower Jungali Khola and the upper Shivgarhi members. The lower member consists of nearly equal amount of fine to coarse grained sandstone and variegated, bioturbated and mottled siltstone beds, with minor amount of marl beds and few calcerte and shale beds. The upper, Shivgarhi Member is characterised by thick medium to coarse grained sandstone with 'salt and pepper' texture, but nearly equal proportion of sandstone and rarely variegated siltstone beds. One molluscan fossil locality, F-4, is found at the lower part of the Shivgarhi Member.

Surai Khola Formation

It is predominantly composed of thick, coarse to very coarse grained 'salt and pepper' sandstone beds and gray to dark gray mudstone with subordinate amount of calcerte, marl and shale beds. Beds containing molluscan fossils are found in lower (SKF-1, -2, -3) and upper (SKF-5, -6, -7) parts of the formation (Fig. 3).

Dobata Formation

It is characterised by predominance of thick greenish grey to grey calcareous mudstone beds, with lesser amount of sandstone and conglomerate beds.

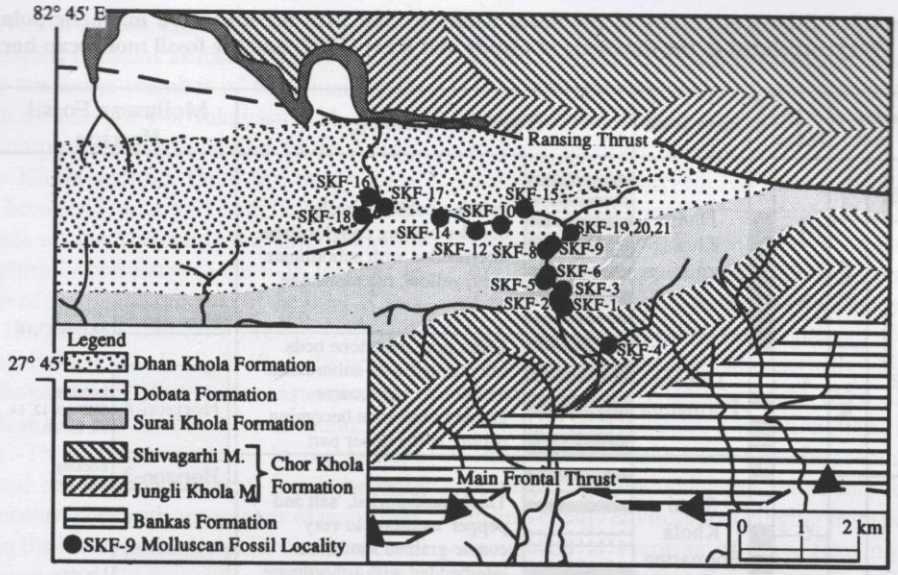


Fig. 3: Generalized geology (after Dhital et al., 1996) of the study area with fossil localities.

Molluscan fossils (SKF-10, -11, -2, -13, -14, -15, -19, -20, -21) are abundant in this formation.

Dhan Khola Formation

It is dominated by pebble and boulder bearing conglomerate with mudstone and subordinate sandstonebeds. Three fossil localities (SKF-16, -17, -18) are identified at the lower most part of this formation.

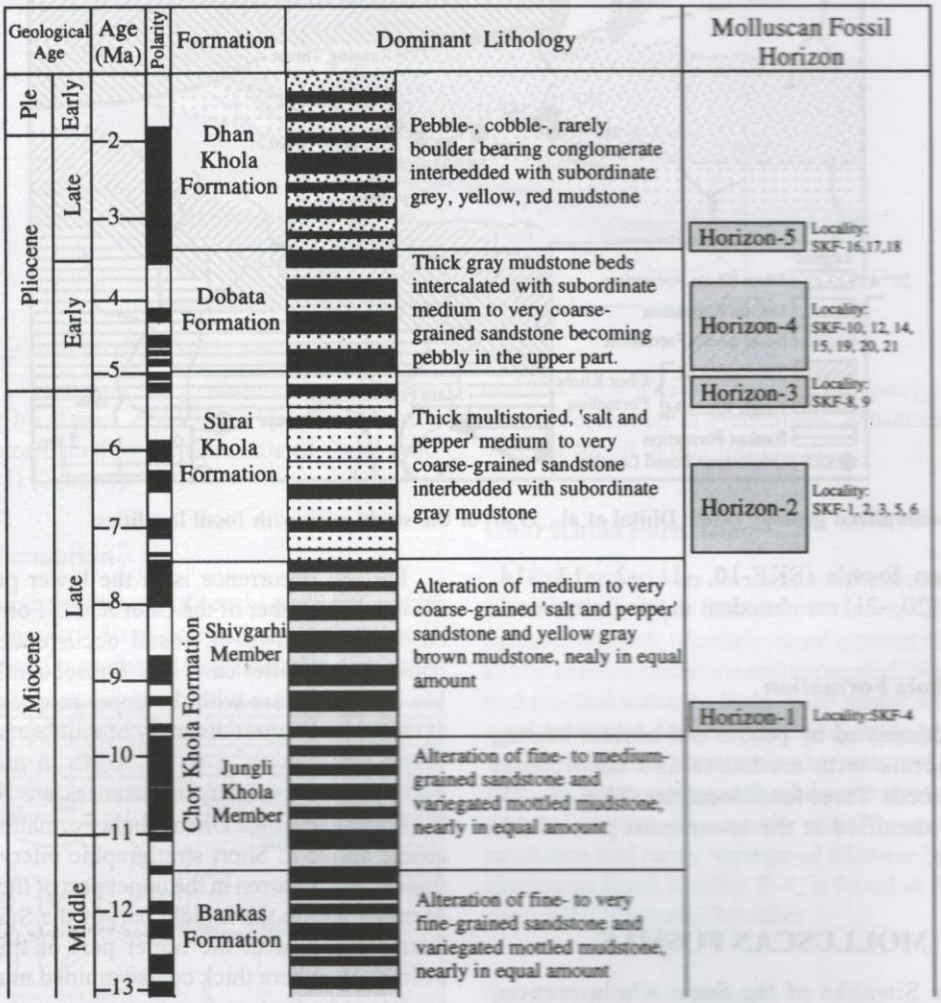
MOLLUSCAN FOSSILS

In the Siwaliks of the Surai Khola section, molluscan fossils are common in the Surai Khola and Dobata formations. Many of the molluscan fossil localities of this section were reported by Shrestha (1993). There are more than 25 fossil localities, however not all have high yield or well preserved specimens. Some shells occur as lag. Fossil localities shown in Fig. 3 are the ones with high yield. The fossils are generally found to occur at the top of the fining-upward sequence in grey to dark grey mudstones to fine grained sandstones of floodplain deposits. At most localities shells are well preserved, and bivalves shells are articulated. Gastropods with well preserved shell sculpture indicate little transport.

Earliest occurrence is in the lower part of the Shivgarhi Member of the Chor Khola Formation, at ca. 9.5 Ma, however, fossil occurrence became common only after ca. 7 Ma. Subsequently, after 4 Ma it became rare with the upper most occurrence at ca. 3 Ma. Highest diversity of molluscan fauna is found between ca. 5 to ca. 4 Ma in the Dobata Formation. Thereafter, occurrences are few up to the lower part of the Dhan Khola Formation and are absent above it. Short stratigraphic interval within this section is barren in the upper part of the Shivgari Member and in the middle part of the Surai Khola Formation, and in the upper part of the Dobata Formation, where thick coarse grained multistoried sandstone bodies are dominant.

The molluscan fossil occurrences are broadly grouped into five Horizons (Table 1) based on the stratigraphic position. In ascending order, Horizon-S1 is composed of only one locality, SKF-4, near the lower part of the Shivgarhi Member. Molluscan assemblage is characterised by *Parreysia ?binaiensis* and *Bellamya* sp. A, *Lamellidens* sp. Shells are poorly preserved in dark brownish gray mudstones which also yield turtle carapace and Chara gyrogonites. In the upper Horizon-S2, consisting of locality SKF-1, -2, -3, -5, and SKF-6, in the lower part of the Surai Khola Formation, has different fauna. Molluscan fossil assemblage is

Table 1: Simplified lithostratigraphy of the Surai Khola section with the measured magnetic polarity (after Appel et al., 1991) correlated to the timescale of Cande and Kent (1995) and the fossil molluscan horizons.



composed of *Melanoides* cf. *tuberculata*, *Indonaia* sp., *Bithynia* sp., *Brotia palaeocostula* and rare *Lamellidens* sp. Horizon-S3, in the upper part of the Surai Khola Formation, consist of locality SKF-8 and -9. The assemblage is characterised by *Bellamya celsispiralis* and *Indonaia narayani* with *Bithynia* sp., *Lamellidens* sp. Horizon-S4, lies in the Dobata Formation, and consists of locality SKF-10, -12, -15 and -14 (locality at saddle point). Many taxa present in this horizon are not present in the lower horizons. This horizon consists of *Paludomus suraiensis*, *Brotia dobataensis*, *Angulyagra shiddarthai*, *Indonaia tenella*, *Pila* sp. and *Bithynia* sp. The uppermost Horizon S5 consists of locality SKF-17, -18 and -16 (Dhan Khola Locality) in the lower part of the Dhan Khola Formation. At locality SKF-17 and 18 the fossil assemblage is dominated of *Bithynia* sp. and *Pila* sp. with rare lower horizon species like *Paludomus suraiensis*, *Brotia dobataensis*, and *Indonaia tenella*. In the upper most locality, SKF-16, of this horizon the assemblage is composed of *Parreysia chureii*, *Lamellidens* sp., *Indonaia tenella*, *Pisidium* sp., *Corbicula* sp., *Brotia* sp., *Melanoides tuberculata*.

The stratigraphical distribution of the fossil horizons in the Surai Khola section correlates well with horizons with fossil localities groupings in the Arung-

Binai-Tinau Khola section. Horizon S1 is at about the same stratigraphic horizons as fossil locality F-65, F-11, F-12, in the lower member of the Binai Khola Formation in the east (Bl-1 of Takayasu et al., 1995), and faunal composition is also similar. In the Arung-Binai-Tinau Khola section, there are many fossil localities in-between Horizon S1 and S2, however, in the Surai Khola section it is found to be barren. Horizon S2 stratigraphically correlates to the F-16 locality, in the lower part of the middle member of the Binai Khola Formation. Horizon S3 and S4 correlate well with fossil locality F-72, F-13, F-18, F-19, F-20 horizon (Bm-2 of Takayasu et al., 1995) in the eastern section. Above this horizon, no fossil locality is found in the Arung-Binai-Tinau Khola section. In the eastern section around ca. 5 Ma, molluscan fossils became common in occurrences with appearance of many taxa not present in the lower parts. A similar occurrence of molluscan fossils at about the same age is observed in the Surai Khola section. The molluscan faunal composition seem to indicate major change around ca. 5 Ma (Fig. 4).

Molluscan faunal diversity is low in the Surai Khola section in comparision to that in eastern section. The fossil specimens identified are shown in Table 2. It is noted that the faunal composition is nearly similar in both sections, however, after ca. 5 Ma, some discrepancy is observed. The gastropod taxa belonging to genus *Paludomus* is not recorded in the eastern Tinau-Binai-Arung Khola section. Similarly, a large bivalve genus *Physunio* dominant in the Arung-Binai-Tinau Khola section is not recorded in the present study area. In addition, fauna in the present study area is dominated by gastropods whereas in the eastern section it is dominated by large bivalves. Such difference in dominant taxa indicates a variation in habitat present. The fossil molluscan fauna from the present study area belongs to genera which are commonly found living in low-energy environment ranging from pond, marsh, lacustrine to margins of slow flowing river, but generally avoid fast flowing waters. The genera identified are more abundant in warmer and humid subtropical to tropical Northeast India and Indo-Malayan peninsula. Further study on the

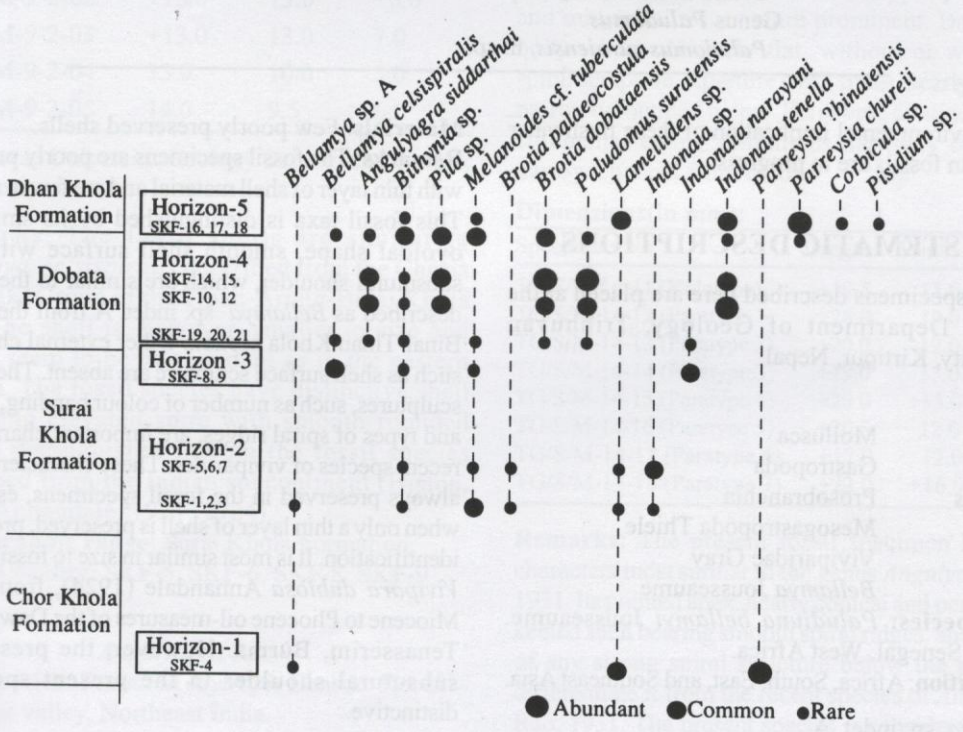


Fig. 4: Fossil Molluscan occurrences and their stratigraphical distribtuion.

Table 2: The list of molluscan taxa from the Late Neogene Siwalik Group, Surai Khola section.

Molluscan Fauna from the Neogene Siwalik Group, Surai Khola Section	
Class Gastropoda	Class Bivalvia
Subclass Prosobranchia	Order Unionida
Order Mesogastropoda	Family Unionidae
Family Viviparidae	Genus *Lamellidens*
Genus *Bellamya*	*Lamellidens* sp. indet.
Bellamya celsispiralis	Genus *Indonaia*
Bellamya sp. indet. A	*Indonaia tenella*
Genus *Angulyagra*	*Indonaia narayani*
Angulyagra siddarthai, n. sp.	Genus *Parreysia*
Family Ampullariidae	*Parreysia ?binaiensis*
Genus *Pila*	*Parreysia chureii*, n. sp.
Pila sp.	Family Corbiculidae
Family Bithyniidae	Genus *Corbicula*
Genus *Bithynia*	*Corbicula* sp.
Bithynia sp.	Family Pisidiidae
Family Thiaridae	Genus *Pisidium*
Genus *Melanoides*	*Psidium* sp.
Melanoides cf. *tuberculata*	
Genus *Brotia*	
Brotia palaeocostula	
Brotia dabataensis, n. sp.	
Genus *Paludomus*	
Paludomus suraiensis, n. sp.	

palaeoenvironmental implication of these freshwater molluscan fossils are in progress.

SYSTEMATIC DESCRIPTIONS

The specimens described here are placed at the Central Department of Geology, Tribhuvan University, Kirtipur, Nepal.

Phylum Mollusca
Class Gastropoda
Subclass Prosobranchia
Order Mesogastropoda Thiele
Family Viviparidae Gray
Genus *Bellamya* Jousseaume
Type species: *Paludiuna bellamyi* Jousseaume. Recent: Senegal, West Africa.
Distribution: Africa, South, East, and Southeast Asia.

Bellamya sp. indet. A

Bellamya sp. indet. A Gurung, Takayasu and Matsuoka, 1997, p.169 , figs. 4.5-8

Materials: Few poorly preserved shells.
Remarks: The fossil specimens are poorly preserved with thin layer of shell material and are few in number. This fossil taxa is distinguished by its small size, ovoidal shape, smooth shell surface with weak subsutural shoulder, which are similar to the species described as *Bellamya* sp. indet. A from the Arung-Binai-Tinau Khola section. Other external characters such as shell surface sculpture are absent. The surface sculptures, such as number of colour banding, number and types of spiral ridges, are important characters in recent species of viviparides. These characters are not always preserved in the fossil specimens, especially when only a thin layer of shell is preserved, preventing identification. It is most similar in size to fossil species *Vivipara dubiosa* Annandale (1924), from Upper Miocene to Pliocene oil-measures of the Dawna Hills, Tenasserim, Burma. However, the presence of subsutural shoulder in the present species is distinctive.

This fossil taxa are found in the earliest fossil molluscan assemblages in association with *Parreysia*

sp. In the present study area, it occurs at about the same stratigraphic horizon as in the Churia (Siwalik) Group in the Tinau-Arung-Binai Khola section (Gurung et al., 1997), east of the present study area, from where it was initially reported. In comparison, its occurrence is rare in the Surai Khola section.
Fossil Locality: SKF-4, SKF-2, SKF-3.
Stratigraphic range: Upper part of the Chor Khola Formation to lower Surai Khola Formation.

Bellamya celsispiralis Gurung, Takayasu and Matsuoka, 1997
Bellamya celsispiralis Gurung, Takayasu and Matsuoka, 1997, p.169 , figs. 4.1-4
Fig. 5(1-4)

Materials: TG/S/M-9-2-01, TG/S/M-9-2-02, TG/S/M-9-2-03, TG/S/M-9-2-04, TG/S/M-9-2-05.

Dimensions (in mm):

Specimen No.	Length	Width	Aperture
TG/S/M*-9-2-01	13.5	8.5	+6.0
TG/S/M-9-2-02	+15.0	13.0	+6.0
TG/S/M-9-2-03	+13.0	13.0	7.0
TG/S/M-9-2-04	13.0	10.0	5.0
TG/S/M-9-2-05	14.0	9.5	6.0

*Tribhuvan University, Geology Department, Siwalik Mollusca

Remarks: The fossil shells are similar to *Bellamya celsispiralis* described from the Churia (Siwalik) Group of the Tinau-Arung-Binai Khola area. The shell is, however, smaller in size and do not seem to be as abundant as in the eastern section. The fossil species have distinctive shell with long elevated spire with smooth rounded whorls distinguishes it from the fossil species described from the Indian subcontinent (Hislop, 1860; Annandale, 1921, 1924).
Stratigraphic range: Surai Khola Formation.
Fossil Locality: SKF-5, SKF-6, SKF-8, SKF-9

Genus *Angulyagra* Rao
Type species: *Paludina oxytropis* Benson. Recent - Manipur valley, Northeast India.
Distribution: Assam, Northwest India and South China.

Angulyagra siddarthai, **sp. nov.**
Angulyagra sp. indet. Gurung, Takayasu and Matsuoka, 1997, p.171, figs. 4.13-15
Fig. 5(5-10)

Materials: TG/S/M-14-11, Holotype; TG/S/M-14-12, Paratype 1; TG/S/M-14-13, Paratype 2; TG/S/M-14-14, Paratype 3; TG/S/M-14-15, Paratype 4; TG/S/M-14-16, Paratype 5; TG/S/M-14-17, Paratype 6; TG/S/M-14-18, Paratype 7.
Diagnosis: Shell slenderly conical, moderately thin but strong, shell surface with smooth spiral ridges, bodywhorl with peripheral keel, apex pointed.
Description: Shell slenderly conical, 20 to 30 mm in length, moderately thin but solid. Younger shell more broadly conical. Apex pointed. Spire conical, short, elevated, with rapidly increasing five to six whorls. Whorl side broadly obliquely flat with subsutural shoulder. Suture shallow. Body whorl large, two third of the shell length with prominent peripheral keel. Shell surface with fine spiral and growth lines, with three comparatively prominent smooth spiral ridges between the subsutural shoulder and peripheral keel. The subsutural, peripheral keel and mid spiral ridges more prominent. Base of the body whorl obliquely flat, without or with weak spiral sculpture. Aperture oval, small, nearly straight, narrowly rounded below. Peristome continuous with columellar callus. Umbilicus narrowly open with narrow channel from below.

Dimensions(in mm):

Specimens No.	Length	Width	Aperture
TG/S/M-14-11 (Holotype)	+19.5	13.0	+10.5
TG/S/M-14-12 (Paratype 1)	+28.0	19.0	+15.0
TG/S/M-14-13 (Paratype 2)	+20.0	12.0	+10.0
TG/S/M-14-14 (Paratype 3)	+19.0	13.0	+10.0
TG/S/M-14-15 (Paratype 4)	+20.0	+15.0	+10.0
TG/S/M-14-16 (Paratype 5)	+20.5	12.0-	
TG/S/M-14-17 (Paratype 6)	+17.0	12.0	+9.0
TG/S/M-14-18 (Paratype 7)	+22.0	+16.0	-

Remarks: The present fossil specimen has shell characters most similar to the genus *Angulyagra* Rao, 1931. Its pointed apex, nearly conical and peripherally keeled shell bearing smooth spiral ridges, and absence of any strong spiral structure below the periphery differentiate it from the recent species of *Angulyagra* Rao, 1931. The present species is considered as new extinct species. Species from Assam, Northeast India, *A. oxytropis* (Benson) has larger shell with strong spiral

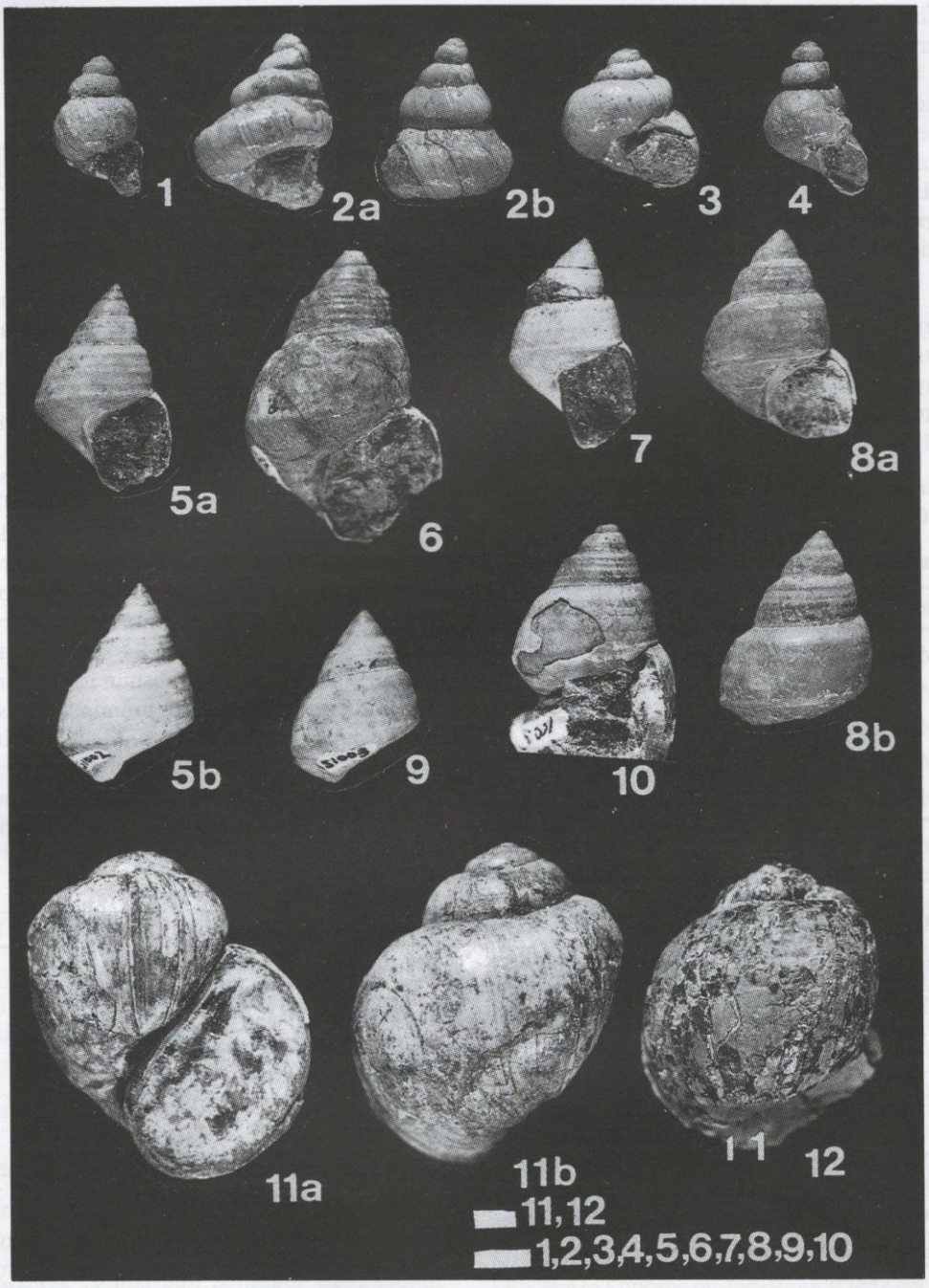


Fig. 5: 1-4 *Bellamya celsispiralis*. 1. GDSF9-2-1; 2a. GDSF9-2-2, apertural view; 2b. adapertural view; 3. GDSF9-2-3; 4. GDSF9-2-4. 5-10 *Angulyagra shiddarthai*, sp. nov. 5a. GDSF14-11, holotype, apertural view; 5b. adapertural view; 6. GDSF14-12, Paratype 1; 7. GDSF14-13, Paratype 2; 8a. GDSF14-15, paratype 4, apertural view; 8b. adapertural view; 9. GDSF14-17, paratype 6; 10. GDSF14-18, paratype 7. 11, 12 Pila sp. 11a. GDSF14-21, apertural view; 11b. adapertural view; 12. GDSF14-22. All scale bars : 5 mm.

sculpture below the periphery, and *A. microchaetophora* (Annandale) has only few weakly developed spiral sculpture. The Chinese species belonging to this genus are with more ovoidal shell with broad coarse spiral ridges (Yen, 1939).

In the Surai Khola area, the present species are common in the fossil locality of the Dobata Formation. Its presence is reported from only one locality in the Binai Khola area (Gurung et al., 1997).

Etymology: The name is in honor of Siddhartha Gautam
Stratigraphic range: Dobata Formation.
Fossil Locality: SKF-14, SKF-15

Family Ampullariidae Guilding
Genus *Pila* Röding
Type species: *Helix ampullacea* Linné. Recent: Asia.
Distribution: Asia and Africa.

Pila sp. indet.
Figs. 5(11-12), 6(1-5)

Materials.— TG/S/M-14-21, TG/S/M-14-22, TG/S/M-14-23, TG/S/M-14-24, TG/S/M-14-25, TG/S/M-10-26, TG/S/M-15-27.

Dimensions (in mm):

Specimen No.	Length	Width	Aperture
TG/S/M-14-21	46.0	39.0	32.5
TG/S/M-14-22	+38.0	+34.0	+27.0
TG/S/M-14-23	+37.0	+29.0	+22.0
TG/S/M-14-24	+43.0	+40.0	+34.0
TG/S/M-14-25(Operculum)	48.0	28.0	4.0*
TG/S/M-10-26(Operculum)	38.5	21.0	4.0*
TG/S/M-15-27(Operculum)	+27.0	17.0	1.5*

Remarks: The present fossil specimens have characteristic shell and the operculum of the genus *Pila* Röding. The shells are turbinate, longer than broad, medium in size, thick and strong with short spire and very rapidly increasing whorls, last body whorl very large, rounded. The opercula are large, thick (upto 4 mm), calcareous, with concentric growth lines with subcentral nucleus. Generally, the shell is poorly preserved, on the contrary opercula are more well preserved. At one locality (SKF-12, Fig. 3) only opercula are found, consisting of thin (1.5 mm) and reddish brown in color.

The identification of the species is based not only on the shell character but also on the colour of the banding, margin of the aperture and the anatomy. Apart from that the ecological variation of the shell shape makes specific level identification difficult. The present fossil shells do not show similarity to the common *P. globosa* Swainson group. A fossil taxa *Pachylabra* (= *Pila*) *prisca* Prashad, 1925, was described from Poonch, Kashmir based on fossil opercula only. The author also found that the fossil opercula are different from that of the common Indian species *P. globosa*. The thick opercula from Kashmir, India are quite similar to the one from the present study area. Without more detail comparison the present fossil shell could not be identified.
Stratigraphic range: Dobata Formation to the lower part of the Dhan Khola Formation.
Fossil Locality: SKF-12, SKF-14, SKF-17, SKF-18.

Family Bithyniidae Fisher
Genus *Bithynia* Leach
Type species: *Helix tentaculata* Linné. Recent: Europe.
Distribution: Europe and Asia.

Bithynia sp. indet.
Fig. 6(6,7)

Materials: Some small poorly preserved shells and comparatively well preserved opercula.
Remarks: The small white calcareous operculum with concentric lines and nearly central nucleus is typical of this family. These are found from the lower part of the Surai Khola Formation to the Lower part of the Dhan Khola Formation, however, shells are less common. The shells as well as opercula occur only at few localities. As the shells are small and fragile, recovering of a complete shell is difficult. Although fossil specimens are placed in the genus *Bithynia* at present, its placement may be changed with the study of more well-preserved shell. The opercula are of different size and shape, which might be due to presence of more than one taxa. The species in the Arung-Binai-Tinau Khola section is different as it has different shell size and shape.
Stratigraphic range: Surai Khola Formation to Lower part of the Dhan Khola Formation.
Fossil Locality: SKF-1, SKF-6, SKF-8, SKF-9, SKF-15, SKF-11, SKF-13, SKF-14, SKF-18, SKF-17 .

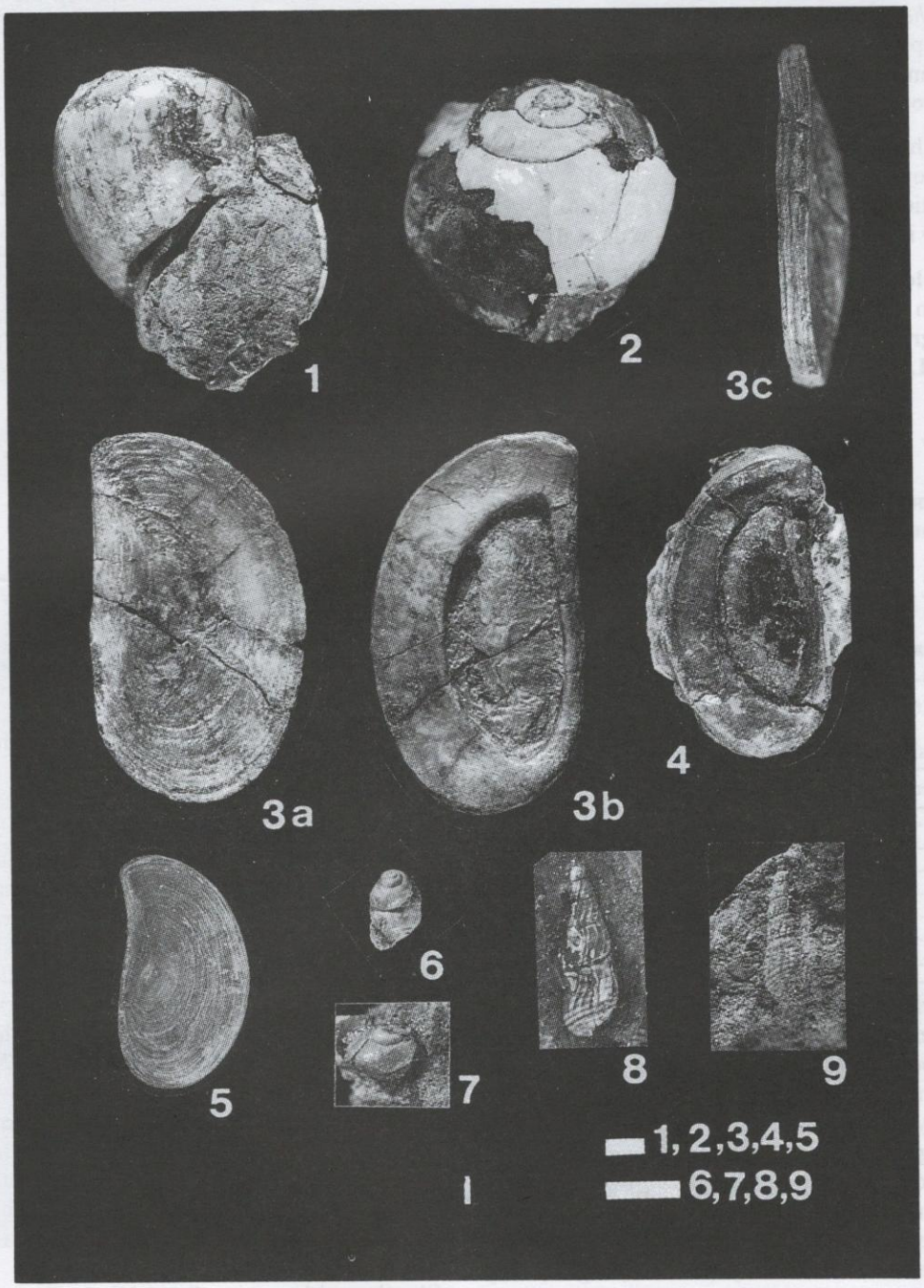


Fig. 6: 1-5 *Pila* sp. 1. GDSF14-24; 2. GDSF14-23; 3a. GDSF14-25, outer view; 3b. inner view; 3c. side view; 4. GDSF10-26, inner view; 5. GDSF12-27, outer view. 6,7 *Bithynia* sp. 8,9 *Melanoides* cf. *tuberculata*. 8. GDSF2-31; 9. GDSF3-32. All scale bars : 5 mm.

Family Thiaridae Gray
Genus *Melanoides* Olivier
Type species: *Melanoides fasciolata* Olivier = *Nerita tuberculata* O. F. Müller. Recent: India.
Distribution: Palaeotropic and subtropics.

Melanoides cf. *tuberculata* (O. F. Müller, 1774)
Fig. 6(8,9)

Materials: TG/S/M-9701, TG/S/M-9702 and few poorly preserved shells.
Remarks: These fossil shells occur at most localities but are common only at few localities. In fossil locality SKF-1, -3, -5, this species is dominant, however, preservation is poor. The shells collected are generally small in size for the genus, ranging in size from 10 to 20 mm. The shells are turreted with prominent axial and spiral ridges covering the shell surface. Fossil taxa belonging to this species are also reported from Upper Siwalik deposit, Punjab, India (Bhatia and Mathur, 1973).

It is widely distributed and inhabit variety of habitat from rivers, ponds, lakes, to even brackish waters.Although not common this species is present at most localities.
Stratigraphic range: Surai Khola Formation to the lower part of the Dhan Khola formation.
Fossil Locality: SKF-1, SKF-2, SKF-3, SKF-5, SKF-7, SKF-16, SKF-17.

Genus *Brotia* H. Adams
Type species: *Melania pagodula* Gould. Recent: Asia.
Distribution: Southeast Asia.

Brotia dobataensis sp. nov.
Brotia sp. A, Gurung, Takayasu and Matsuoka, 1997, p.174, figs. 6.1-3
Fig. 7(1-6)

Materials: TG/S/M-14-41 (Holotype); TG/S/M-14-42 (Paratype 1); TG/S/M-14-43 (Paratype 2); TG/S/M-14-44 (Paratype 3); TG/S/M-14-45 (Paratype 4); TG/S/M-14-46 (Paratype 5); TG/S/M-14-47 (Paratype 6); TG/S/M-14-48 (Paratype 7); TG/S/M-14-49 (Paratype 8)
Diagnosis: Shell turreted with obliquely flat whorls, shallow suture, shell surface with prominent broad axial ribs and fine spiral threads with peripheral blunt spine.

Description: Shell, turreted, elongated conical in shape, 35 to 45 mm in length, thick, dextral. Apex eroded in all specimens. Spire long. Composed of gradually increasing five to six remaining whorls with nearly obliquely flat sides. Body whorl moderately large and a little rounded. Suture shallow with a spiral thread parallel just below it. Shell surface with prominent regular broad axial ribs crossed by weak spiral threads, four to five between the suture and the periphery. The ribs slightly bulging at the periphery, forming blunt spine in larger specimens. The axial ribs do not continue below the periphery, basal part with fine eight to nine spiral threads only. Aperture not completely preserved. Partially preserved aperture seems to be small, oval, nearly straight. Umbilicus closed.

Dimensions (in mm):

Specimen No.	Length	Width	Aperture
TG/S/M-14-41 (Holotype)	+34.0	+16.0	+14.0
TG/S/M-14-42 (Paratype 1)	+39.0	+15.0	-
TG/S/M-14-43 (Paratype 2)	+43.0	17.0	+15.0
TG/S/M-14-44 (Paratype 3)	+36.0	25.0	+18.0
TG/S/M-14-45 (Paratype 4)	+42.0	26.0	+17.0
TG/S/M-14-46 (Paratype 5)	+36.0	17.0	+13.0
TG/S/M-14-47 (Paratype 6)	+25.0	13.0	+10.0
TG/S/M-14-48 (Paratype 7)	+21.0	9.0	+8.0
TG/S/M-14-49 (Paratype 8)	+16.0	7.0	+6.0

Remarks: The species of genus *Brotia* is at present distributed from India, Burma, Malay Peninsula, Sumatra to Java, South China, and the most widely distributed species is *B. costula* (Rafinesque). The present fossil species show similarity in shell morphology with *B. costula* (Rafinesque), however, the fossil species can be distinguished by its more prominent axial rib sculpture and weaker spiral sculpture, with obliquely flat whorls. The fossil taxa *B. palaeocostula* Gurung, Takayasu and Matsuoka, 1997, from the Churia Group, west-central Nepal, has more stronger surface sculpture with much protruding blunt spines. Another fossil species, *Brotia* sp. A, reported from the same area, is similar to the present species. Report on the occurrence of fossil taxa belonging to this group

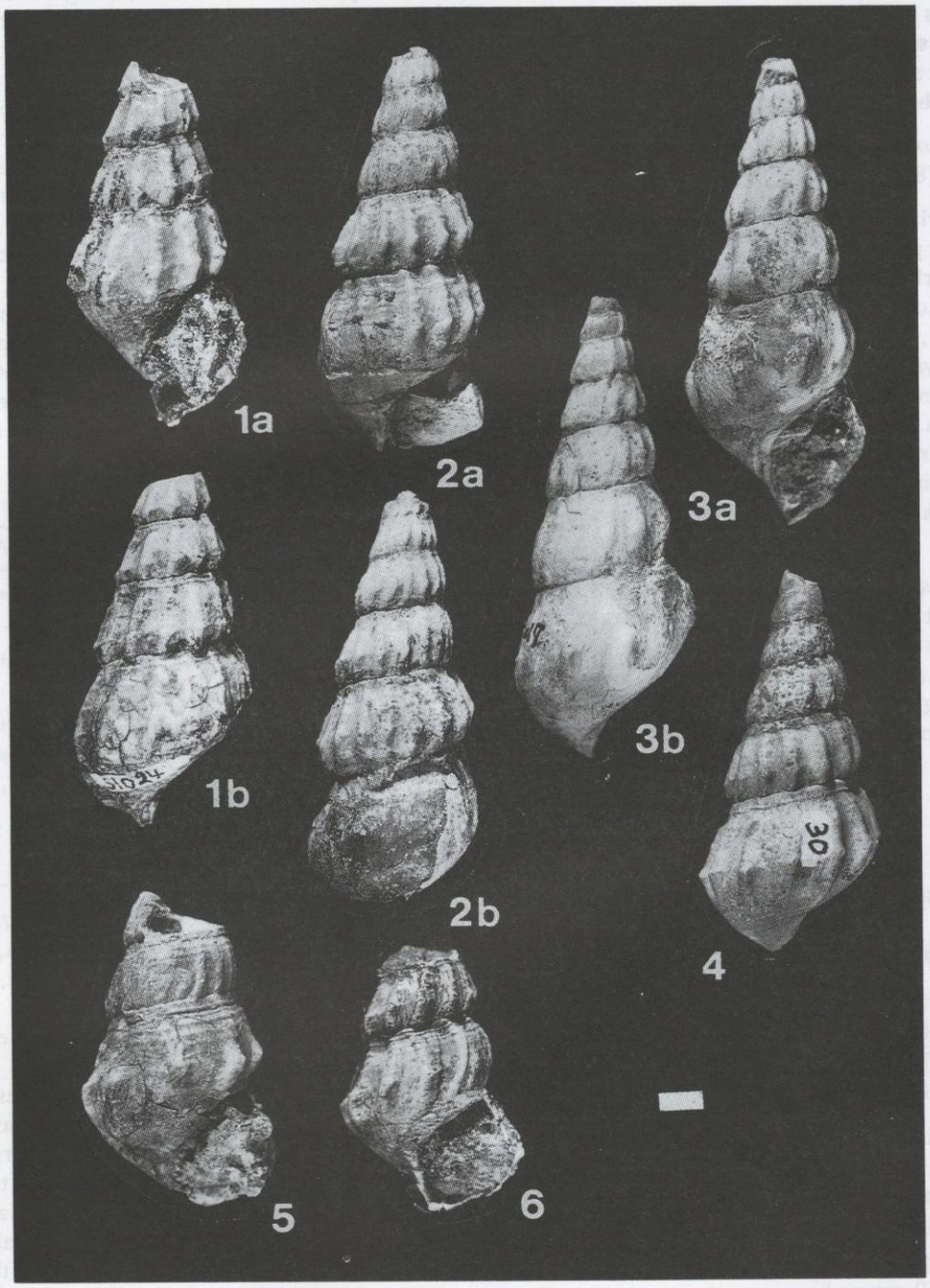


Fig. 7: 1-6 *Brotia dobataensis*, sp. nov. 1a. GDSF14-41, holotype, apertural view; 1b. adapertural view; 2a. GDSF14-42, paratype 1, apertural view; 2b. adapertural view; 3a. GDSF14-43, paratype 2, apertural view; 3b. adapertural view; 4. GDSF14-46, paratype 5; 5. GDSF14-45, paratype 4; 6. GDSF14-44, paratype 3. Scale bar : 5 mm.

are mainly from Burma. Fossil species *B. intermedium* (Annandale, 1924), and *B. cotteri* (Annandale, 1924), are reported from upper Miocene to Pliocene oil shale of Dawna Hills, Tenasserim, Burma. These two fossil species are larger and have more well developed reticulate pattern on the shell surface.

Etymology: The name is after the nearby village from where fossil specimens are collected.

Stratigraphic range: Dobata Formation.

Fossil Locality: SKF-14, SKF-15.

Genus *Paludomus* Swainson

Type species: *Melania conica* Gray. Recent: India.

Distribution: South- and Southeast Asia.

Paludomus suraiensis sp. nov.
Fig. 8(1-9)

Materials: TG/S/M-14-61 (Holotype); TG/S/M-14-62 (Paratype 1); TG/S/M-14-63 (Paratype 2); TG/S/M-14-64 (Paratype 3); TG/S/M-14-65 (Paratype 4); TG/S/M-14-66 (Paratype 5); TG/S/M-14-67 (Paratype 6); TG/S/M-14-68 (Paratype 7); TG/S/M-14-69 (Paratype 8); TG/S/M-1470 (Paratype 9); TG/S/M-14-71 (Paratype 10); TG/S/M-14-72 (Paratype 11); TG/S/M-14-73 (Paratype 12).

Diagnosis: Shell ovoid-conical in shape with short elevated conic spire; shell surface with many regular fine spiral grooves with prominent subsutural spiral groove below shallow suture.

Description: Shell ovoid-conical, medium for the genus, moderately thin, solid and light brown in colour. Apex bluntly pointed. Spire conical, short, elevated, composed of 3-4 rapidly increasing whorls, whorl sides a little rounded. Suture shallow with a distinct subsutural spiral groove just below it. Body whorl large and rounded. Shell surface smooth with fine growth lines and fine regular spiral grooves, continuing to the basal part of the body whorl, spiral sculpture more prominent above and below periphery. Aperture moderately large, elongated oval, rounded below, a little narrow above, slightly inclined. Peristome not expanded, probably continuous, columellar callus developed. Umbilicus closed.

Dimensions (in mm):

Specimen No.	Length	Width	Aperture
TG/S/M-14-61 (Holotype)	+14.5	+8.0	+8.0
TG/S/M-14-62 (Paratype 1)	11.5	6.0	6.0
TG/S/M-14-63 (Paratype 2)	+14.5	+9.0	+9.0
TG/S/M-14-64 (Paratype 3)	+11.0	6.0	+6.0
TG/S/M-14-65 (Paratype 4)	+14.0	10.0	+9.0
TG/S/M-14-66 (Paratype 5)	+14.5	8.0	8.5
TG/S/M-14-67 (Paratype 6)	+15.5	8.5	+8.5
TG/S/M-14-68 (Paratype 7)	+15.5	9.0	-
TG/S/M-14-69 (Paratype 8)	+14.0	8.5	+9.0
TG/S/M-14-70 (Paratype 9)	+13.0	8.0	-
TG/S/M-14-71(Paratype10)	+13.0	8.0	-
TG/S/M-14-72(Paratype11)	+12.5	+7.0	+8.0
TG/S/M-14-73(Paratype12)	+11.0	7.5	-

Remarks: Recent species of the genus *Paludomus* Swainson is distributed in the hilly streams of Sri Lanka, South India, Burma, Malay Archipelago. The present fossil shells show more similarity in shell morphology to the recent Burmese species of this genus then to those of the Sri Lanka and south Indian ones. The Burmese species *P. parvula* Rao, 1929, is most similar with rounded whorls and spiral ridges, however, the present fossil species is smaller in size, has ovoidal-conic shape with weaker surface sculpture. This genus has not been reported from Siwaliks or other freshwater deposits of similar age of the Indian subcontinent.

Etymology: The species name is given after the Surai Khola flowing near the fossil locality.

Stratigarphic range: Upper part of the Surai Khola Formation, the Dobata Formation and lower part of the Dhan Khola Formation.

Fossil Locality: SKF-15, SKF-14, SKF-17, SKF-18, SKF-19. SKF-20, SKF-21.

Class Bivalvia

Order Unionida

Family Unionidae Fleming

Genus *Lamellidens* Simpson, 1900

Type species: *Unio marginalis* Lamarck. Recent: East India.

Distribution: South Asia.

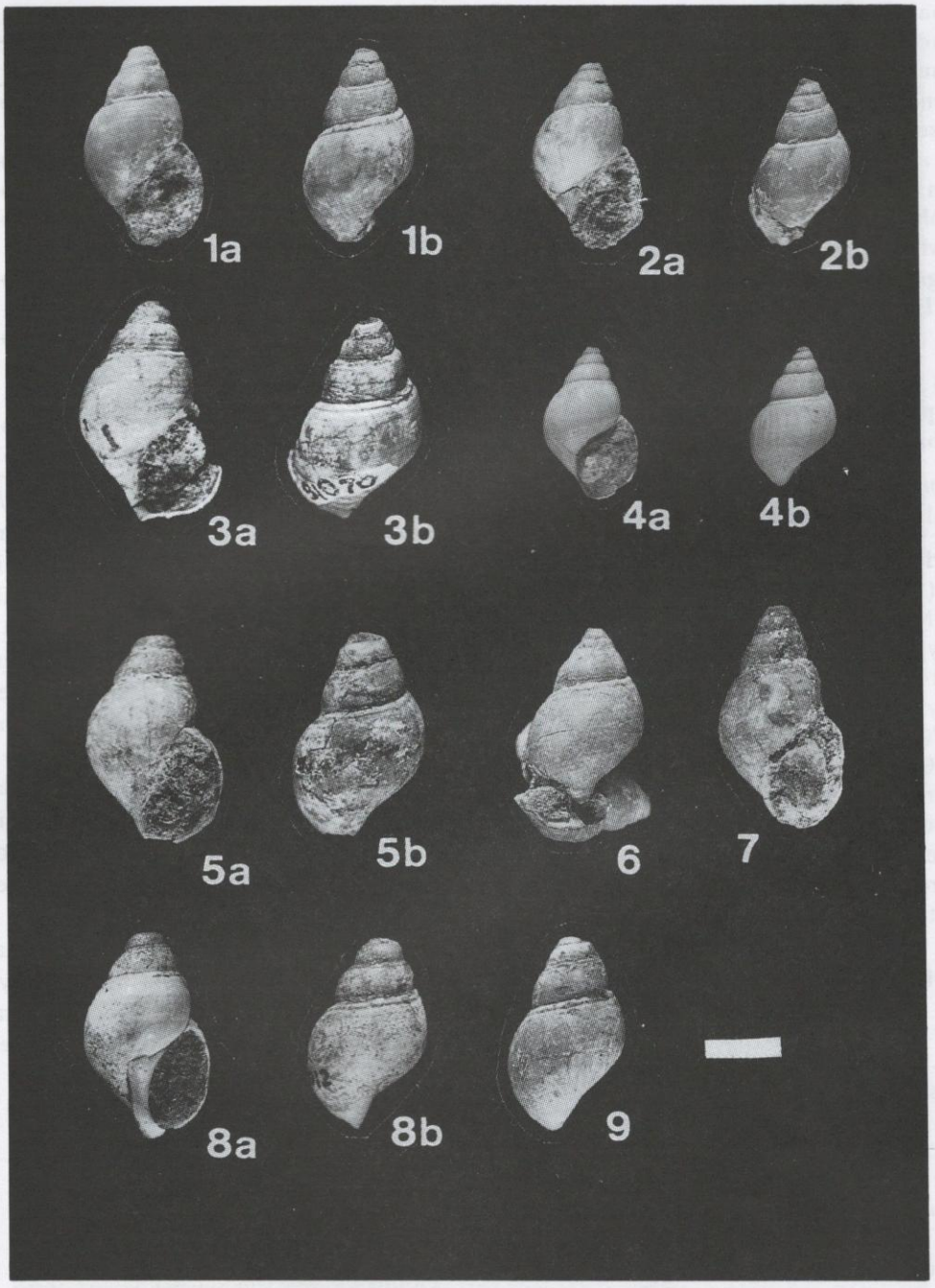


Fig. 8: 1-9 *Pauldomus suraiensis*, sp. nov. 1a. GDSF14-61, holotype, apertural view, 1b. adapertural view; 2a. GDSF14-62, paratype 1, apertural view, 2b. adapertural view; 3a. GDSF14-63, paratype 2, apertural view, 3b. adapertural view; 4a. GDSF14-64, paratype 3, 4b. adapertural view; 5a. GDSF14-65, paratype 4, apertural view; 5b. adapertural view; 6. GDSF14-70, paratype 9; 7. GDSF14-67, paratype 6; 8a. GDSF14-69, paratype 8, apertural view, 8b. adapertural view; 9. GDSF14-71, paratype 10. Scale bar : 5 mm.

Lamellidens sp. indet.
Fig. 9(1, 2)

Materials: Few incomplete shells.
Remarks: Some large sized but incomplete bivalve shells are collected with other molluscan fossils. Though incomplete, inferred shape of the shell mould and size is most similar to genus *Lamellidens* Simpson. The moulds are of different shapes and sizes, indicating presence of more than one taxa. Diversity of this genus is high in Burma. The common widely distributed species in the Indian subcontinent, *Lamellidens marginalis,* is distributed from south Pakistan to Burma. In the freshwater molluscan fauna of the Churia Group, west-central Nepal, (Takayasu et al., 1995) this genus is well represented. Its occurrence in the Surai Khola seems comparatively rare and poorly preserved.
Stratigraphic range: Upper part of the Shivgarhi Member of the Chor Khola Formation to the Lower Dhan Khola Formation.
Fossil Locality: SKF-4, SKF-1, SKF-16, SKF-15.

Genus *Indonaia* Prashad, 1918
Type species: *Unio caeruleus* Lea. Recent: West Bengal, India.
Distribution: South and Southeast Asia.

Indonaia tenella Takayasu, Gurung and Matsuoka, 1995
Indonaia tenella Takayasu, Gurung and Matsuoka, 1995, p. 164, figs. 4.12-14.
Fig. 9(3-7)

Materials: TG/S/M-15-101, TG/S/M-14-102, TG/S/M-16-103, TG/S/M-16-104, TG/S/M-16-105, TG/S/M-16-106, TG/S/M-16-107, TG/S/M-16-108.

Dimensions (in mm):

Specimens	Length	Width	Thickness	Valve
TG/S/M-15-101	40.0	25.0	-	Right
TG/S/M-14-102	+44.0	25.0	20.5	Both
TG/S/M-16-103	28.0	17.0	9.0	Both
TG/S/M-16-104	28.5	17.0	+6.0	Right
TG/S/M-16-105	27.0	17.0	+6.0	Right
TG/S/M-16-106	31.0	17.0	+10.0	Both
TG/S/M-16-107	19.0	12.0	+5.0	
TG/S/M-16-108	+33.0	+20.0	-	Both

Descriptive remarks: Takayasu et al. (1995), described *Indonaia tenella,* from the Siwalik Group, west-central Nepal, based on few fossil specimens in which internal structures were not observed. The fossil shells from the present area is similar and is identified as this species. The above description is given to supplement the previous one as the present specimens are more complete.

Shell much inflated, elongated rounded trapezoid in shape, medium in size for the genus, moderately thin. Anterior margin short and narrow, not regularly rounded; dorsal margin long, gently curved; ventral margin long broadly curved, nearly straight in the middle; posterior margin forming two weak angulation at the place of termination of posterior ridge. Posterior ridge long broadly rounded, weakly bifurcating from the middle. Posterior slope formed into long narrow wing. Umbo small, very anteriorly placed, at one third the shell length from anterior, not prominent, only a little rising. Ligament just posterior to the umbo, long, dark brown in color, rising above shell margin. Umbonal part and dorsal slope with faint radial chevron ribs, shell surface with irregular coarse and fine growth lines. Dentition moderately thick. Pseudocardinal small, triangular, incised; one in the right valve and two in the left valve. Posterior lateral lamellar, long, nearly straight; one in the right valve and two in the left valve.

Apart from previously stated species, it shows close relationship to the recent *I. caeruleus* (Lea), and *I. khadakvaslaensis* Ray, 1966, in shell morphology. However, in *I. caeruleus* (Lea) dentition is thinner and pseudocardinal is more lamellar. *I. khadakvaslaensis*, is more elongated with much narrower posterior wing. The fossil species *I. tenella* has comparatively well developed dentition with short triangular pseudocardinal and long laterals, valves of thuis species are more inflated with narrower wing.
Stratigraphic Range: Dobata Formation to lower part of Dhan Khola Formation
Fossil Locality: SKF-15, SKF-14, SKF-16

Indonaia narayani Takayasu, Gurung and Matsuoka, 1995
Indonaia narayani Takayasu, Gurung, Matsuoka,

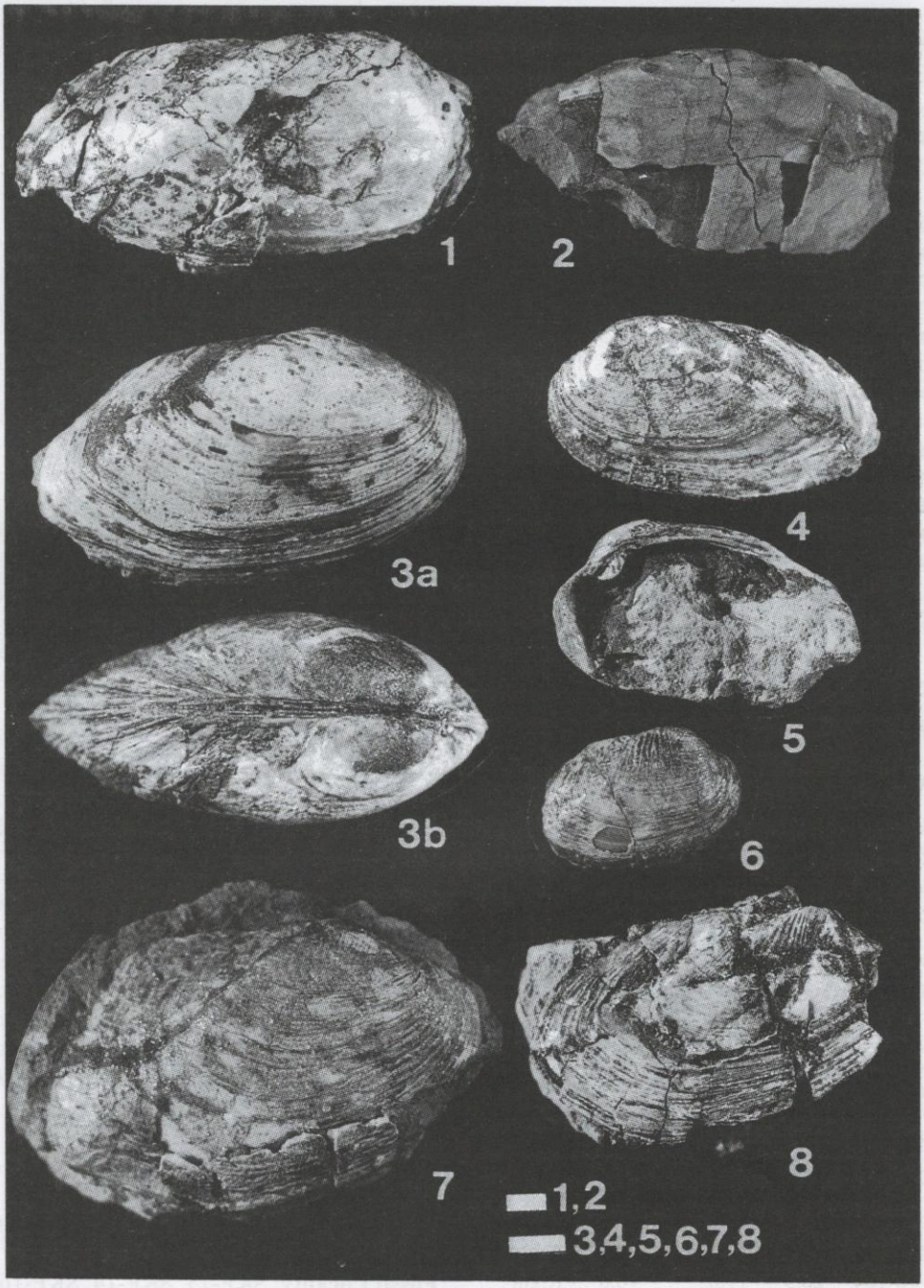


Fig. 9: 1-2 *Lamellidens* sp.; 3-7 *Indonaia tenella*; 3a. GDSF14-102, right valve, 3b. umbonal view; 4. GDSF16-106, left valve; 5. GDSF16-104, inner view; 6. GDSF16-107, right valve; 7. GDSF15-101, right valve; 8. GDSF16-108, right valve. All scale bars : 5 mm.

Materials: TG/S/M-3-505, TG/S/M-3-507, TG/S/M-3-506, TG/S/M-8-501, TG/S/M-8-502, TG/S/M-8-503, TG/S/M-8-504, TG/S/M-8-520, TG/S/M-8-521.

Dimensions (in mm):

Specimens	Length	Width
TG/S/M-3-81	+40.0	+25.0
TG/S/M-3-82	+38.0	+24.0
TG/S/M-3-83	+38.0	+22.0
TG/S/M-8-91	+35.0	+18.0
TG/S/M-8-92	+38.0	+25.0
TG/S/M-9-1-93	+30.0	+24.0
TG/S/M-9-1-94	+30.0	+25.0
TG/S/M-9-1-95	+23.0	+18.0

Remarks: Generally the collected fossil shells are deformed and only partially preserved. The elongated oval to subtriangular shell with narrowly rounded anterior and bluntly pointed posterior, and small narrow posterior wing, is similar to the species described as *Indonaia narayani* Takayasu, Gurung and Matsuoka, 1995.

Stratigraphic range: Surai Khola Formation

Fossil Locality: SKF-8, SKF-9.

Genus *Parreysia* Conrad

Type species: *Unio multidentatus* Philippi. Recent: India.

Distribution: Southeast Asia and Africa.

Parreysia ?binaiensis
Fig. 11(1, 2)

Materials: TG/S/M-4-111, TG/S/M-4-112, TG/S/M-4-113, few poorly preserved specimens.

Dimensions (in mm):

Specimen No.	Length	Width
TG/S/M-4-111	+23.0 mm	+22.0 mm
TG/S/M-4-112	+25.0 mm	+17.0 mm
TG/S/M-4-113	+22.0 mm	26.0 mm

Remarks: Shell preservation is poor, generally shell mould with thin shell layer. The shell small in size for the genus, rounded triangular in shape, posterior truncated, with thin outer layer half of it covered with radial chevron sculpture. Comparison with other species is difficult at present. Although smaller in size, shell shape show resemblance to *Parreysia binaiensis* Takayasu, Gurung and Matsuoka, 1995.

Stratigraphic range: Lower part of the Shivgarhi Member, Chor Khola Formation.

Fossil Locality.—SKF-4.

Parreysia chureii, sp. nov.
Figs. 11(3-9)

Materials: TG/S/M-16-121 (Holotype), TG/S/M-16-123 (Paratype1), TG/S/M-16-122 (Paratype2), TG/S/M-16-124 (Paratype3), TG/S/M-16-125 (Paratype4), TG/S/M-16-129 (Paratype5), TG/S/M-16-126 (Paratype6), TG/S/M-16-130 (Paratype7), TG/S/M-16-131 (Paratype8).

Diagnosis: Shell rounded subtriangular; thick; anterior half of the shell longer; anterior margin broadly rounded, posterior margin sharply truncate nearly vertical; umbo subcentral, not prominent, rounded and anteriorly directed.

Description: Shell rounded subtriangular, medium in size for the genus. Valves moderately inflated, equivalve, inequilateral, thick, solid. Anterior half of the shell longer than the posterior half of the shell. Anterior margin broadly rounded, posterior margin truncate nearly vertical. Dorsal margin short, irregularly curved, nearly straight in front, ventral margin gently curved. Ligament just posterior to umbo, external, long, dark brown in color. Umbo subcentral, on the anterior half of the shell, not very prominent, rounded and anteriorly directed. Umbonal area with concentric chevron ridges, in small ones extending to half the shell region. Most part of the shell surface smooth with irregular fine and coarse concentric growth lines. Posterior ridge distinct, broadly rounded, terminating at the base of the truncation. Hinge plate thick, wide with short interdentum. Pseudocardinal triangular strongly ridged, outer ridge prominent in the smaller shells, in the larger ones 4 to 5 ridges radiating from just below umbo. Posterior laterals not very long, slightly curved to nearly straight; one in the right valve and two in the left valve. Umbonal cavity narrow, deep. Anterior muscle scar deep, triangular, posterior muscle scare oval shallow. Pallial line entire, faintly impressed.

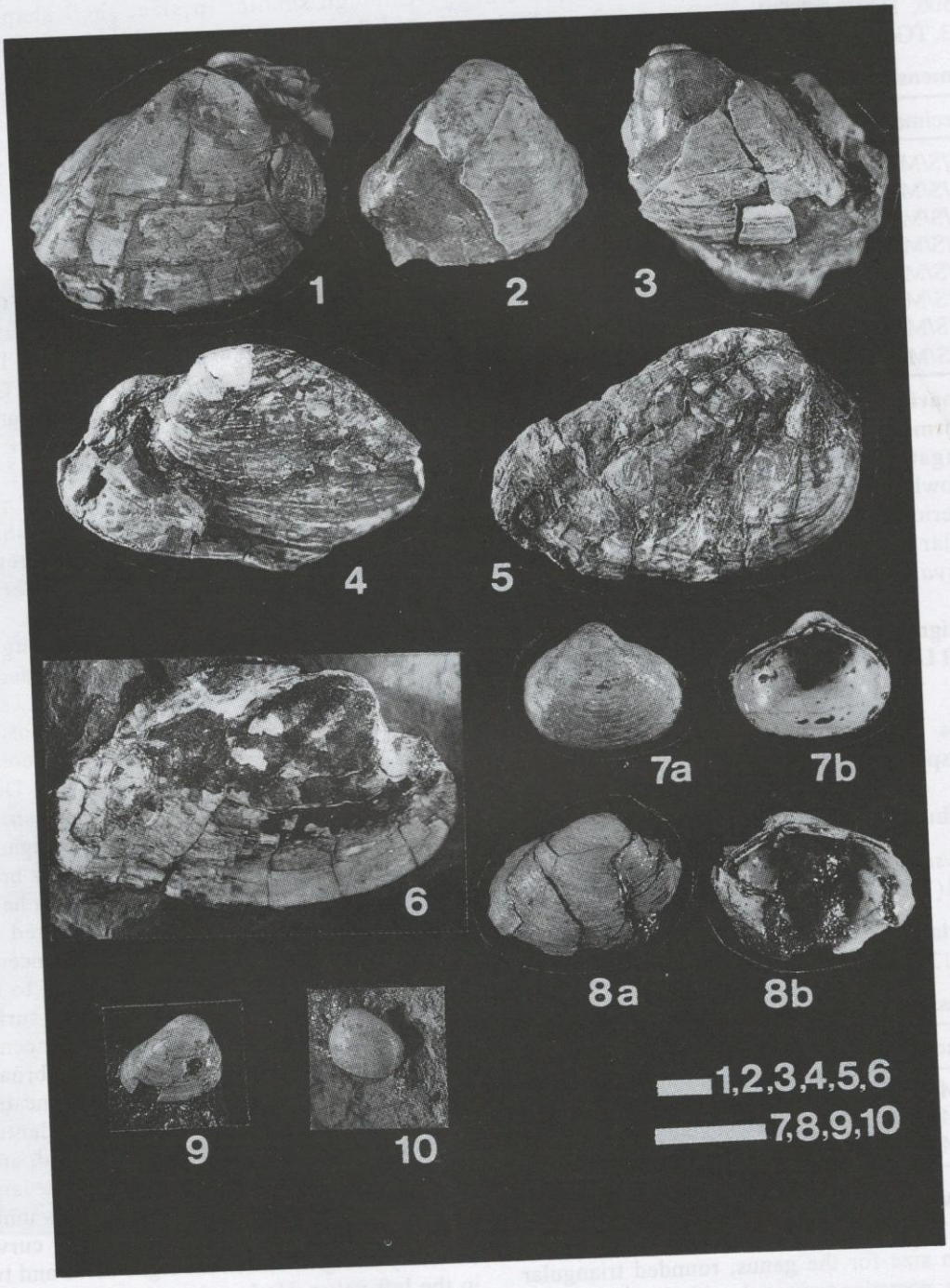


Fig. 10: 1-6 *Indonaia narayani* ; 1.GDSF9-1-93, right valve; 2. GDSF9-1-94, right valve; 3. GDSF9-1-95, left valve; 4. GDSF8-91, left valve; 5. GDSF8-92, right valve; 6. GDSF3-82, right valve; 7, 8 *Corbicula* sp., 7a. outer view, 7b. inner view; 8a. outer view, 8b. inner view; 9, 10 *Pisidium* sp. All scale bars : 5 mm.

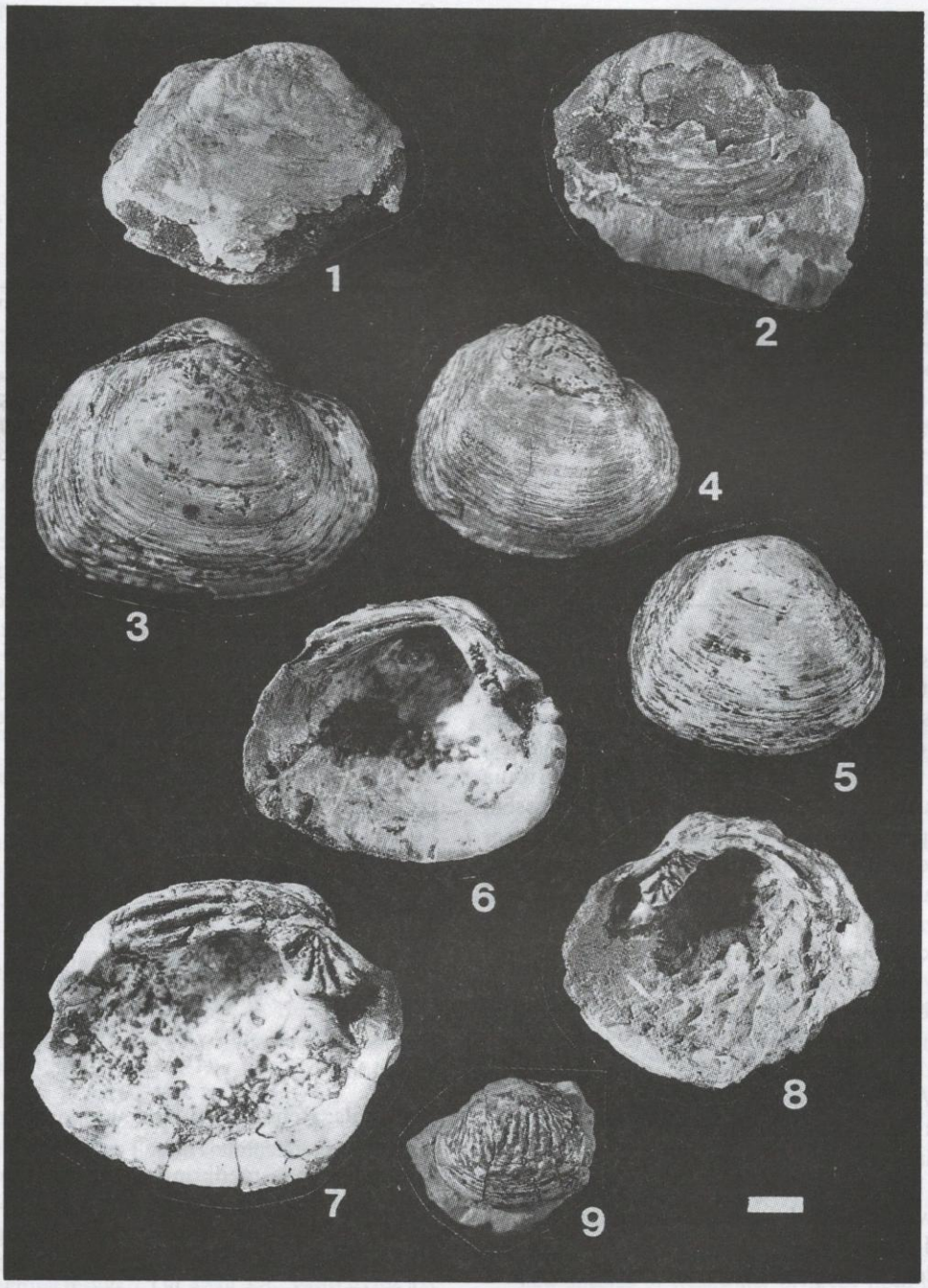


Fig. 11: 1-2 *Parreysia* sp. indet.; 3-9 *Parreysia chureii*, sp. nov. ; 3. GDSF16-123, paratype 1, 4. GDSF16-121, holotype; 5. GDSF16-125, paratype 4; 6. GDSF16-122, paratype 2; 7. GDSF16-124, paratype 3; 8. GDSF16-126, paratype 6; 9. GDSF16-130, paratype 7. Scale bar : 5 mm.

Dimensions (in mm):

Specimen No.	Length	Width	Thickness	Valve
TG/S/M-16-121 (Holotype)	25.6	22.5	16.4	Both
TG/S/M-16-123 (Paratype1)	34.6	28.0	20.3	Both
TG/S/M-16-122 (Paratype2)	28.0	23.8	10.0	Left
TG/S/M-16-124 (Paratype3)	+33.0	29.0	9.5	Left
TG/S/M-16-125 (Paratype4)	24.5	21.0	9.0	Right
TG/S/M-16-129 (Paratype5)	29.0	26.0	10.0	Right
TG/S/M-16-126 (Paratype6)	+28.6	25.2	8.0	Right
TG/S/M-16-130 (Paratype7)	+15.0	12.5	-	Left
TG/S/M-16-131 (Paratype8)	+16.0	14.0	-	Left
TG/S/M-16-127	45.5	37.0	15.0	Left
TG/S/M-16-128	34.0	30.0	15.5	Both

Remarks: The species belonging to the genus *Parreysia* Conrad, are distributed in the Indian subcontinent with eastern most occurrences from Burmese-Thai border. Fossils of this genus are reported from the Siwaliks of Pakistan (Vokes, 1935, 1936) and from similar age rocks of Burma (Annandale, 1924; Prashad, 1930). The present fossil species has anterior half of the shell longer than the posterior half with thick dentition plate, distinguishing it from *Parreysia binaiensis* and *Parreysia zigzagicostata* described from the Siwalik Group, Tinau-Arung-Binai Khola area (Takayasu et al. 1995). The fossil species described from the Siwaliks of Pakistan (*Parreysia tatrotensis* Vokes, 1935) is more triangular with much curved hinge plate. The recent *P. triembolus* (Benson), distributed in the Ganges basin from Morarabad to west Bengal and Nerbada River is similar to this species in shell shape, however, it has larger and more raised umbo with rounded ventral margin and slightly pointed posterior.

Etymology: The species name is taken from the hills of these the rock unit.

Stratigraphic range: Lower part of the Dhan Khola Formation.

Fossil Locality: SKF-16.

Family Corbiculidae
Genus *Corbicula*, Megerle von Muhlfeld
Type species: *Tellina fluminalis* O. F. Müller. Recent: China.
Distribution: Asia, Africa and Australia.

Genus *Corbicula* sp.
Fig. 10(7, 8)

Materials: TG/S/M-16-141, TG/S/M-16-142

Dimensions (in mm):

Specimen No.	Length	Width
TG/S/M-16-141	8.0	6.0
TG/S/M-16-142	+9.0	+6.0

Remarks: Very rare in the fossil assemblage, probably due to its small size. Shell elongated subquadrate in shape, longer than wide, small in size for the genus, moderately thick. Ventral margin long and nearly straight; longer and narrower anterior and posterior rounded with posterior. Umbo small and protruding, subcentral, anteriorly placed. Shell surface with fine concentric straie. Dental plate strong with two or three radiating cardinals, two thin laterals on each sides. The dental morphology is most similar to that of genus *Corbicula*, whoever, more specimens are needed to confirm it.

Stratigraphic Range: Lower part of the Dhan Khola Formation.

Fossil Locality: SKF-16

Family Pisidiidae
Genus *Pisidium* Pfeiffer
Type species: *Tellina amnicum* O. F. Müller
Distribution: Cosmopolitan.

Genus *Pisidium* sp.
Figs. 10(9, 10)

Materials: Represented by few poorly preserved specimens.

Remarks: It is medium in size for the genus, posteriorly elongated triangular in shape, moderately thick. Anterior short widely rounded, long gently rounded ventral, posterior, narrowly rounded. Umbo subcentral, anterior, rounded protruding. The dental character of the shell is important for species identification, whoever, it is difficult to observe in the present fossil shells.

Stratigraphic Range: Lower part of the Dhan Khola Formation.
Fossil Locality: SKF-16.

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