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FRESHWATER MOLLUSCS FROM THE UPPER PLEISTOCENE SEDIMENTS OF THE NARMADA VALLEY, CENTRAL INDIA: PALAEOECOLOGICAL IMPLICATIONS

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ABSTRACT

We carried out the invertebrate palaeontological studies between Jabalpur and Devakachar. Two sections, namely Bhedaghat section and Devakachar section, located 12 km and 120 km respectively southwest of Jabalpur and belonging to the Hirdepur Formation were studied. One fossiliferous horizon each at both the sites was found to be rich in molluscs, e.g. gastropods and bivalvia. Eighteen species of freshwater gastropods and one species of bivalvia were recovered from the two sections. Out of these, four new species of gastropods, e.g. *Lymnaea theobaldi*, *Tricula bhatiai*, *Digoniostoma annandalei* and *Planorbis narmadaensis* are reported for the first time. The bivalves are represented by *Pisidium mitchelli*. This is the first attempt to reconstruct the landscape structure around the environment of *Homo erectus* by using invertebrate fossils. The faunal assemblage appears to belong to four distinct habitats, viz., still water, riverine, open scrub and savannah woodland. Still-water habitat seems to be the major habitat in the study area.

Keywords: Freshwater molluscs, Upper Pleistocene, Narmada valley, Palaeoecology

INTRODUCTION

Narmada, the largest river in Central India, originates at the Plateau of Amarkantak (22^{0}40'N;81^{0}40'E) on the Maikala Range in East Madhya Pradesh at an elevation of about 1,057 m above sea level. The course of the river is straight, controlled by the east-west lineament (Figure 1a). Between Bhedaghat near Jabalpur and Hoshangabad, the river Narmada descends by about 9 m forming a trough in which above 50 m thick Quaternary sediments have preserved a rich fauna. A fossil calvarium of *Homo erectus*, recovered from the secondary basal gravel at Hathnora (Sonakia, 1984; de Lumley and Sonakia, 1985; Sonakia and Biswas, 1998) has made Narmada valley an important site for palaeontological studies. To date, this is the only documented fossil of early man in India. The Narmada deposits, divided into seven lithostratigraphic formations based on the critical appraisal of multiple parameters (Tiwari and Bhai, 1997), are palaeomagnetically dated as ca. 0.73 ma BP near the base (Agrawal *et al.,* 1988; Rao *et al*., 1997), ca. 74 ka BP in the middle level based on the Toba ash datum (Acharyya and Basu, 1993) and the Holocene at the top (Sankhyan, 2005). The need for a better understanding of the ecology of the area is especially important from the perspective of environment of the *H. erectus*. Although the vertebrates have been briefly discussed for palaeoecological study (Patnaik, 1995; Patnaik *et al*., 1995; Cameron *et al*., 2004), the invertebrate fauna which is considered a very good indicator of ecology has been totally ignored. The present study makes the first attempt to describe the invertebrate fauna of the valley in detail along with palaeoecological significance.

LITHOSTRATIGRAPHY

Tiwari and Bhai (1997) identified seven lithostratigraphic formations in the composite lithostratigraphy of the Narmada sequence. The Surajkund Formation, yielding the fossils of *H. erectus*, is sandwiched between the Dhansi Formation and the Hirdepur Formation (Fig.1a). A tephra layer between the Baneta and the Hirdepur Formations is associated with 0.2 m thick pebble bed containing chert clasts and stone implements and the ash was perhaps derived from the silicic volcanic explosion in Mt. Toba, Sumatra (Mukhopadhyay and Ramachandra, 1997). The present study area forms a part of the Hirdepur Formation comprising homogenous grey calcareous silt interlayered with medium-coarse sand, gravel and cemented conglomerate with high degree of calcification (Fig. 1b). The Hirdepur Formation, coarser than underlying Baneta Formation, is widely distributed and covers most of the alluvial plain (Tiwari and Bhai, 1997). Two sections, namely, the Bhedaghat and the Devakachar (Fig. 1b) belonging to the Hirdepur Formation (Rao *et al.,* 1997; Tiwari and Bhai, 1997) were studied. Both the sections are lithologically correlated (see Fig. 1b) by a cemented conglomerate (a marker bed used for correlating most Narmada sections (Rao *et al.,* 1997). Several levels of both profiles were sampled. However, only one horizon was found to be productive in each section.

The Bhedaghat section (23^{0}08'N:79^{0}56'E), exposed by the river Narmada, is composed of clay, sand and unconsolidated gravel (Fig. 1b). The fossiliferous horizon, 15 m above the base, is a 0.7 m thick medium to coarse-grained, grayish-sand bed. The Devakachar section (23^0 23'N:79^0 07'E), exposed along the river Sher (a tributary of the Narmada, see Fig. 1a) is characterized by cemented conglomerate, sand and yellowish silt (Fig. 1b). The fossil horizon, 8.5 m above the base, is a 0.5 m thick coarse pebbly sand bed.

CHRONOLOGY OF THE DEPOSITS

On the basis of the presence of large mammals, Biswas (1997) proposed two distinct faunal zones in the Narmada valley, as (a) the lower assemblage (Surajkund Formation) comprising *Homo erectus-Stegodon namadicus-Elephas namadicus* (narrow mollared)-*Hexaprotodon namadicus-Sus namadicus-Cuon alpinus* and (b) the upper assemblage (Baneta and Hirdepur Formations) consisting of *Elephas*

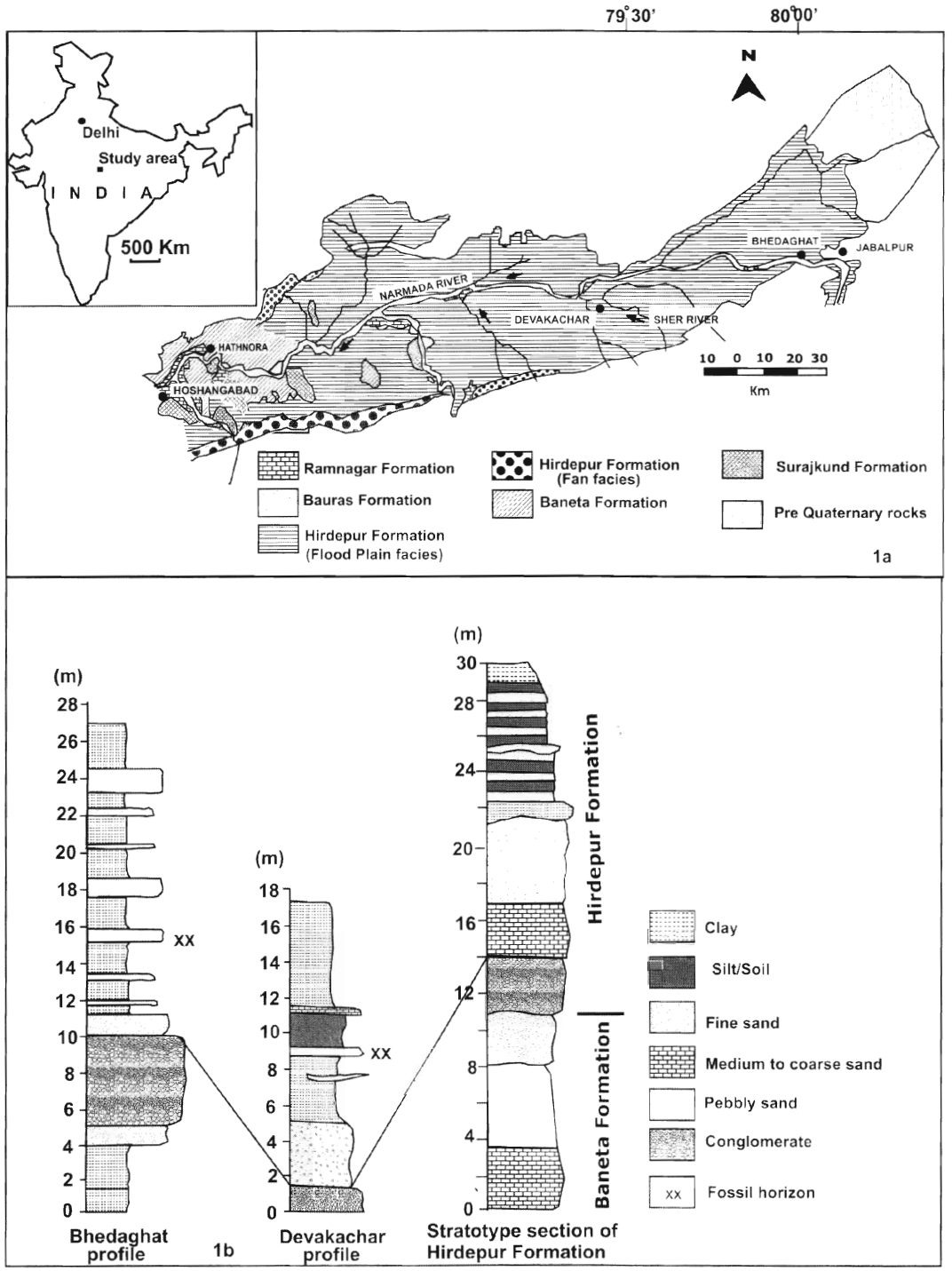


Fig. 1a. Geological map of Narmada valley (after Tiwari and Bhai, 1997). 1b. Lithostratigraphy of Bhedaghat and Devakachar section and Hirdepur Formation (modified after Kotlia and Joshi, 2008).

namadicus (broad mollared)-*Equus hemionus khur-Hexaprotodon palaeindicus-Hystrix crassidens*. The age of the Hirdepur Formation is late Pleistocene (Biswas, 1997), base of which (ca. 126 ka BP) is considered here as equivalent to the base of the Tarantian or base of Marine Isotope Stage 5e and base of the Eemian Interglacial Stage (Shackleton *et al.*, 2003). Palaeomagnetic investigations indicate that the Surajkund, Baneta and Hirdepur Formations show normal polarity within the Brunhes Normal Chron (Table 1), whereas the Dhansi Formation belongs to the uppermost part of the Matuyama reversed Chron (Rao *et al.*, 1997). The tephra layer, dated at the boundary of the Baneta and Hirdepur Formations (Table 1), is equivalent to the Toba ash of ca. 74 ka BP (Acharyya and Basu, 1993). Therefore, until now, the maximum precise age given to the *H. erectus* horizon is between 0.73 ma BP to 74 ka BP (Sonakia and Biswas, 1998; Acharyya and Basu, 1993). Further, from archaeological view-point, the abundance of bifacially worked implements of handaxe-cleaver assemblages of the Acheulean techno-complex has been attributed as the work of the *H. erectus* in South Asia (Corvinus, 2004).

Table 1: Stratigraphy, chronology, fauna and climate of the Narmada sequence (modified after Kotlia and Joshi, 2008).

Chronology (Tiwari & Bhai, 1997; Sonakia & Biswas, 1998; Acharyya & Basu, 1993)	Magneto-stratigraphy (Rao *et al.*, 1997)	Lithostratigraphy (Tiwari & Bhai, 1997; Rao *et al.*, 1997)	Faunal assemblage (Biswas, 1997; Tiwari & Bhai, 1997; Sonakia & Biswas, 1998)	Palaeoclimate (Biswas, 1997; Tiwari & Bhai, 1997)
• 13 ka BP	Brunhes Normal Chron	Hirdepur Formation	Upper assemblage (*Elephas namadicus* (narrow mollared), *Hexaprotodon palaeindicus*, *Equus hemionus khur*)	Warm and humid with minor arid oscillations
• 74 ka BP		Baneta Formation		Warm and humid conditions
• 700 ka BP		Surajkund Formation	Lower assemblage (*Homo erectus*, *Elephas namadicus* (broad mollared), *Equus namadicus*, *Sus namadicus*, *Hexaprotodon namadicus*)	
	Matuyama Reversed Chron	Dhansi Formation	Fragmentary fossils	

The climatic conditions during the deposition of *H. erectus* (Surajkund Formation) and our fossil material (Hirdepur Formation) were almost similar except for minor spikes of arid oscillations (see Table 1) later.

METHODOLOGY AND REPOSITORY

Both the sites were found to be extremely rich in the gastropod fauna. Devakachar site was found to be richer in the fossil content. Approximately 100 kg material was collected from both the sites. The invertebrate fauna (gastropods and bivalves) was recovered by bulk screening of the fossiliferous horizons. The matrix was subjected to wet sieving (16, 25, 40, 60 ISTM mesh size). The collected material consists of 18 species of freshwater gastropods and one species of bivalves. The shell dimensions are given in tables 2-3. The fossil material is housed in the Palaeontological laboratory of the Department of Geology, Kumaun University, Nainital. In the text, NAR stands for Narmada.

SYSTEMATIC PALAEONTOLOGY

Phylum **Mollusca**
Class **Gastropoda**
Subclass **Pulmonata**
Order **Basommatophora**
Superfamily **Lymnaeoidea** Rafinesque, 1815
Family **Lymnaeidae** Rafinesque, 1815
Subfamily **Lymnaeinae** Rafinesque, 1815
Genus ***Lymnaea*** Lamarck, 1799

Lymnaea theobaldi n. sp.

(Pl. I, figs. a, b; Pl. IV, figs. a-b)

Derivation of Name: Named in the honour of W. Theobald for his contribution to the stratigraphy of Narmada valley.

Holotype: NAR/ 2067, a complete shell (Pl. I, figs. a-b).

Paratypes: NAR/2057, 2061, 2064, 2065, 2068, all complete shells.

Type locality: Bhedaghat, 12 km southwest of Jabalpur (M.P.); Devakachar, 120 km southwest of Jabalpur (M.P.).

Horizon and age: Medium to coarse grained sand. Hirdepur Formation (Upper Pleistocene).

Referred material: NAR/2051-2054 (Bhedaghat); NAR/ 2055- 2068 (Devakachar), all complete shells and several slightly broken shells.

Diagnosis: Shell small sized and elongate,, slender, sutures inclined, spire short, body whorl more than 2/3rd of the entire shell, faint vertical striations on the external surface, apex sub-rounded, spiral angle 50^0.

Description: The shell is long and slender in appearance. The apex is sharply pointed and the spiral angle is 50^0. There are two spiral whorls. The sutures are inclined. Very faint vertical striations can be seen on the surface. The body whorl is large but slender, tapering posteriorly. The aperture is elliptical and holostomatus. The orientation of the shell is dextral. Shell dimensions are given in table 2.

Remarks: *Lymnaea theobaldi* n. sp. is different from the adult *Lymnaea* sp. (Bhatia and Mathur, 1973) in having a much smaller size and lesser number of spiral whorls. Compared to *Lymnaea* (*Galba*) *andersoniana* (Bhatia, 1974), the present forms have a slender appearance with a smaller apical angle and elongated aperture. The apical angle in *Lymnaea acuminata* (Bhatia, 1974) is larger than the present *Lymanea theobaldi* n. sp.

Lymnaea sp.

(Pl. I, fig.c)

Referred material: NAR/1051-1065 (Bhedaghat); NAR/ 1066- 1080 (Devakachar), all complete shells and several slightly broken shells.

Description: The shell has one spiral whorl in the juvenile and two in the adult shell and a large body whorl. The body whorl is more than 2/3rds of the entire shell and is elongated towards the posterior. The aperture is large, broad in the middle but tapering towards the base. Surface is etched with fine apertural striations. The spiral angle is 45^0. The sutures between the whorls are more or less horizontal and deeply incised. The orientation of the shell is dextral and the aperture is holostomatous. Shell dimensions are given in table 2.

Superfamily **Ampullarioidea** Gray, 1824
Family **Viviparidae**
Subfamily **Viviparinae**

Table 2: Measurements of conispiral shells.

Species	Mean length (mm)	Mean width (mm)	Mean aperture height (mm)	Mean aperture width (mm)
Lymnaea theobaldi n. Sp. (n= 17)	5.116	2.168	3.642	1.647
Lymnaea sp. (n= 30)	2.99	1.443	2.447	1.122
Viviparus bengalensis (n= 25)	5.21	4.878	3.096	2.626
Viviparus dubiosus (n= 20)	5.812	4.897	2.345	2.123
Gulella bicolor (n= 25)	3.383	1.321	0.993	0.578
Tricula montana (n=16)	3.311	1.535	1.243	0.715
Tricula bhatiai n. sp. (n= 50)	3.313	1.783	1.166	1.057
Digoniostoma annandalei n. sp. (n= 13)	2.528	1.491	1.62	1.159
Digoniostoma sp. (n= 25)	2.808	2.504	1.624	1.399
Melanoides tuberculata (n=50)	14.644	5.417	4.073	2.615
Succinea indica (n=50)	3.693	2.265	2.887	1.776
Succinea sp. (n=25)	1.927	1.314	1.512	0.945

Genus ***Viviparus*** Montfort, 1810

Viviparus bengalensis (Lamarck) Prashad, 1928

(Pl. I, figs. d-e)

Paqludina bengalensis Lamarck, 1822, p.17 4

Viviparus bengalensis (Lamarck) Lydekker, 1882, p. 106-107

Viviparus bengalensis (Lamarck) Germain, 1914, p. 42-43

Vivipara bengalensis (Lamarck) Annandale, 1921, p. 362-367

Vivipara bengalensis (Lamarck) Annandale, 1924, p. 97-104

Viviparus bengalensis (Lamarck) Prashad, 1928, p. 162-163, pl. 19, fig.1

Viviparus bengalensis (Lamarck) Bhatia and Mathur, 1973, p. 41-42, fig. 5

Referred material: NAR/1001-1010 (Bhedaghat); NAR/1011-1025 (Devakachar), complete and a few broken shells.

Description: The shell is turbinate having a short spire with the number of whorls ranging from 2-3. The body whorl is ¾th of the entire shell. The apex is pointed. Spiral angle is 90^0. The sutures are well marked and horizontal. The body whorl is globose. The aperture is rounded and wide. It is holostomatus and dextral in orientation. Shell surface is faintly striated with axial ornamentation. Horizontal growth lines can be seen. Shell dimensions are given in table 2.

Remarks: *Viviparus bengalensis,* a widespread Indian species, was earlier known to occur only in the Pleistocene of the Narmada valley. Later, Bhatia and Mathur (1973) reported this species from the Pinjor Siwalik. Compared to the Pinjor forms, the Narmada forms are bigger with a square aperture, whereas the Pinjor forms have a rounded aperture.

Viviparus dubiosus (Annandale)

(Pl. I, figs. f-g)

Viviparus dubiosa Annandale, 1924, p. 100-101, pl. 7, figs. 4, 4a

Viviparus dubiosa (Annandale) Prashad, 1928, p. 193.

Viviparus dubiosus (Annandale) Bhatia and Mathur, 1973 p. 42, fig. 5 (12)

Referred material: NAR/51-60 (Bhedaghat); NAR/61-70 (Devakachar), all complete shells and a few broken shells.

Description: The shell is globose with a pointed apex. The spire is short and is about $1/3^{rd}$ of the total length of the specimen. Spiral angle is 85^0. The body whorl is large and globose. The specimen exhibits dextral coiling. The surface of the shell lacks axial or spiral ornamentation. The aperture is wide, holostomatous and posteriorly elongated due to the presence of a columella. Shell dimensions are given in table 2.

Remarks: In India, *Viviparus dubiosus* was recorded for the first time from the Upper Siwalik of Panjab (Bhatia and Mathur 1973). Compared to the Siwalik forms, the Narmada forms are much bigger with a mean length of 6.93 mm and a width of 6.1 mm.

Order **Stylommatophora**

Family **Streptaxidae**

Subfamily **Straptaxinae**

Genus ***Gulella*** Pfeiffer, 1856

Subgenus ***Huttonella*** Pfeiffer, 1856

Gulella (*Huttonella*) *bicolor* Hutton, 1834

(Pl. I, figs. h-i)

Pupa bicolor Hutton, 1834, p. 86-93

Ennea bicolor (Hutton) Blanford and Godwin-Austen, 1908, p. 19-21, fig. 12

Ennea bicolor (Hutton) Annandale and Prashad, 1920, p. 193

Gulella (Huttonella) bicolor (Hutton) Benthem Jutting, 1950, p. 504, 505, figs. 106, 107

Gulella (Huttonella) bicolor (Hutton) Bhatia and Mathur, 1973, p. 47-48, fig. 5(10)

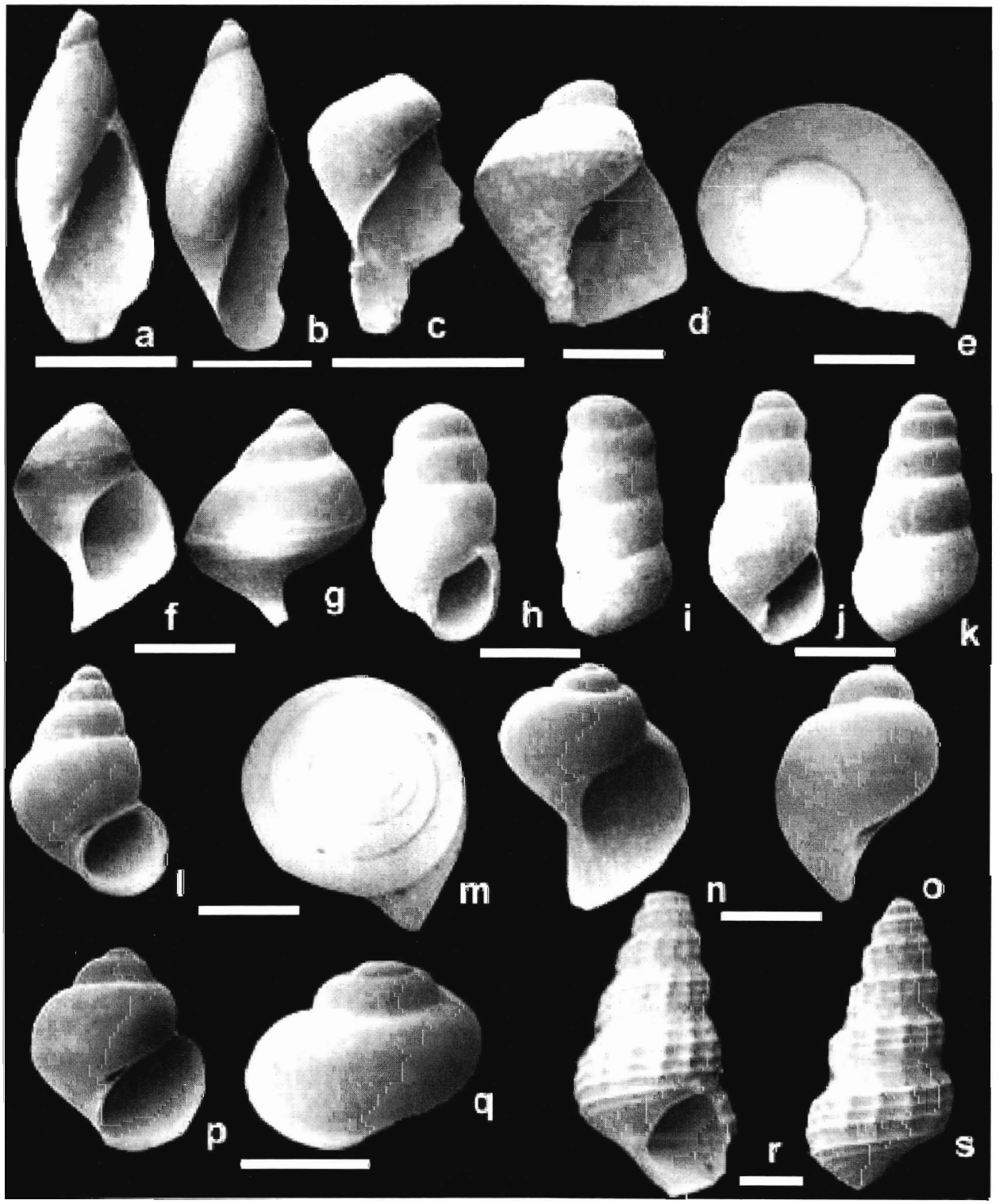
Referred material: NAR/851-860 (Bhedaghat); NAR/861-875 (Devakachar), complete and incomplete shells and several

EXPLANATION OF PLATE I

(Bar scale 1mm)

a-b (NAR/2057, 2067), ***Lymnaea theobaldi*** n. sp.;
c (NAR/ 1054), ***Lymnaea*** sp.;
d-e (NAR/1005, 1007), ***Viviparus bengalensis*** (Lamarck);
f-g (NAR/54, 60), ***Viviparus dubiosus*** (Annadale);
h-i (NAR/ 868, 874), ***Gulella bicolor*** Hutton;
j-k (NAR/706, 707), ***Tricula montana*** Benson;
l-m (NAR/350), ***Tricula bhatiai*** n. sp.;
n-o (NAR/ 140), ***Digoniostoma annandalei*** n. sp.;
p-q (NAR/619, 612), ***Digoniostoma*** sp.;
r-s (NAR/203, 205), ***Melanoides tuberculata*** Müller

Plate I



broken ones.

Description: The shell is long and multispiral with minimum two whorls in the juvenile shells and maximum six whorls in the adult shells. The apex is blunt, cap shaped and rounded. The spire is longer than the body whorl. The spire and the body whorl have roughly the same width throughout, which gives the sides a more or less parallel appearance. The spiral angle is 10-15^0. The aperture is denticulate and has a dextral orientation. The sutures are deeply incised and are also gently inclined. Surface ornamentation is axial. Shell dimensions are given in table 2.

Remarks: This is a carnivorous and circumtropical species commonly found in the open plains of the Indian subcontinent. Earlier, it has been reported from the Panjab Siwaliks (Bhatia and Mathur, 1973). The Siwalik forms are bigger than the Narmada forms.

Order **Mesogastropoda**
Family **Pomatiopsidae**
Subfamily **Triculinae**
Genus ***Tricula*** Benson, 1843
Tricula montana Benson, 1843
(Pl. I, figs. j-k)

Tricula montana Benson, 1843, p. 467
Tricula montana (Benson) Preston, 1915, p. 68
Tricula montana (Benson) Prashad, 1922, p. 16
Tricula sp. Bhatia and Mathur, 1973, p. 44, fig. 5(9)

Referred material: NAR/702-710 (Bhedaghat); NAR/711-718 (Devakachar), all complete shells and several broken shells.

Description: The shell is multispiral with the number of whorls ranging from 4 in the juvenile shells to 5 in the adults. The apex is rounded. The sutures are well marked and more or less horizontal. The body whorl is moderately globose and is bigger than the spire. The aperture is holostomatous and is oval in appearance. There are very fine axial striations on the shell. The spiral angle is 30^0. The shell has a dextral orientation. Shell dimensions are given in table 2.

Remarks: This species was originally reported from North India (Prashad, 1922) and subsequently reported by Bhatia & Mathur (1973) from the Upper Siwalik of Panjab. The Siwalik forms are smaller than the Narmada forms and have comparatively more bulbous body whorl.

Tricula bhatiai n. sp.
(Pl. I, figs. l-m; Pl. IV, figs. c-d)

Derivation of name: Named in the honour of Prof. S. B. Bhatia for his contribution to Invertebrate Palaeontology.

Holotype: NAR/350, a complete shell (Fig. 2l-m, 5c-d).

Paratypes: NAR/308, 315, 326, 348-349, all complete shells.

Type locality: Bhedaghat, 12km southwest of Jabalpur (M.P.); Devakachar, 120km southwest of Jabalpur (M.P.).

Horizon and age: Medium to coarse grained sand. The horizon is Upper Pleistocene.

Referred material: NAR/301-325 (Bhedaghat); NAR/326-350 (Devakachar), all complete shells and some broken shells.

Diagnosis: Shell small, turbinate, spire short, body whorl globose, sutures deeply incised and horizontal, spiral angle 60^0 (Fig. 2l-m, 5c-d).

Description: The shell is turbinate having a short spire, made up of 2-3 whorls. The sutures are deeply incised and horizontal. The apex is rounded. The spiral angle is 60^0. The body whorl is globose and is larger than the spire. The aperture is wide with distinct outer and inner lips. It is dextral and holostomatous in orientation. The surface is smooth without ornamentation. Shell dimensions are given in Table 2.

Remarks: The Narmada forms are similar to *Tricula montana* in the shape of the body whorl. But the spire is shorter and the spiral angle is more acute which gives the spire a sharp and pointed appearance.

Family **Bitliymiidae**
Genus ***Digoniostoma*** Annandale, 1920
Digoniostoma annandalei n. sp.
(Pl. I, figs. n-o; Pl. IV, figs. e-f)

Derivation of name: Named in the honour of Dr. N. Annandale for his contribution to Invertebrate Palaeontology.

Holotype: NAR/140, nearly complete shell with broken aperture (Fig. 2n-o, 5e-f).

Paratypes: NAR/ 138, 144, all incomplete shells.

Type locality: Bhedaghat, 12 km southwest of Jabalpur (M.P.); Devakachar, 120 km southwest of Jabalpur (M.P.).

Horizon and Age: Medium to coarse-grained sand. The horizon is Upper Pleistocene.

Referred material: NAR/131-134 (Bhedaghat); NAR/135-144 (Devakachar), nearly complete shells and several broken shells.

Diagnosis: Shell small, spire short, sutures superficial, although broken, aperture perhaps siphonostomatous, spiral angle 85^0, distinct outer and inner lips of the aperture (2n-o, 5e-f).

Description: The shell is small with a small spire and acute spiral angle (85^0). The body whorl is large, tapering towards the posterior. Although broken, the aperture seems as siphonostomatous. The surface is finely striated with axial ornamentation. The orientation of the shell is dextral. The body whorl has a constricted anterior part or neck and is more than ¾th of the entire shell length. Shell dimensions are given in Table 2.

Remarks: The present species is different from the one, reported by Bhatia and Mathur (1973) in having a much smaller size, a posteriorly elongated siphonostomatous aperture and constricted anterior part of the body whorl.

Digoniostoma sp. Annandale, 1920
(Pl. I, figs. p-q)

Digoniostoma sp. Bhatia and Mathur, 1973, p 42- 43, Fig. 6 (9)

Referred material: NAR/601-610 (Bhedaghat); NAR/611-625 (Devakachar), all complete shells and several broken shells.

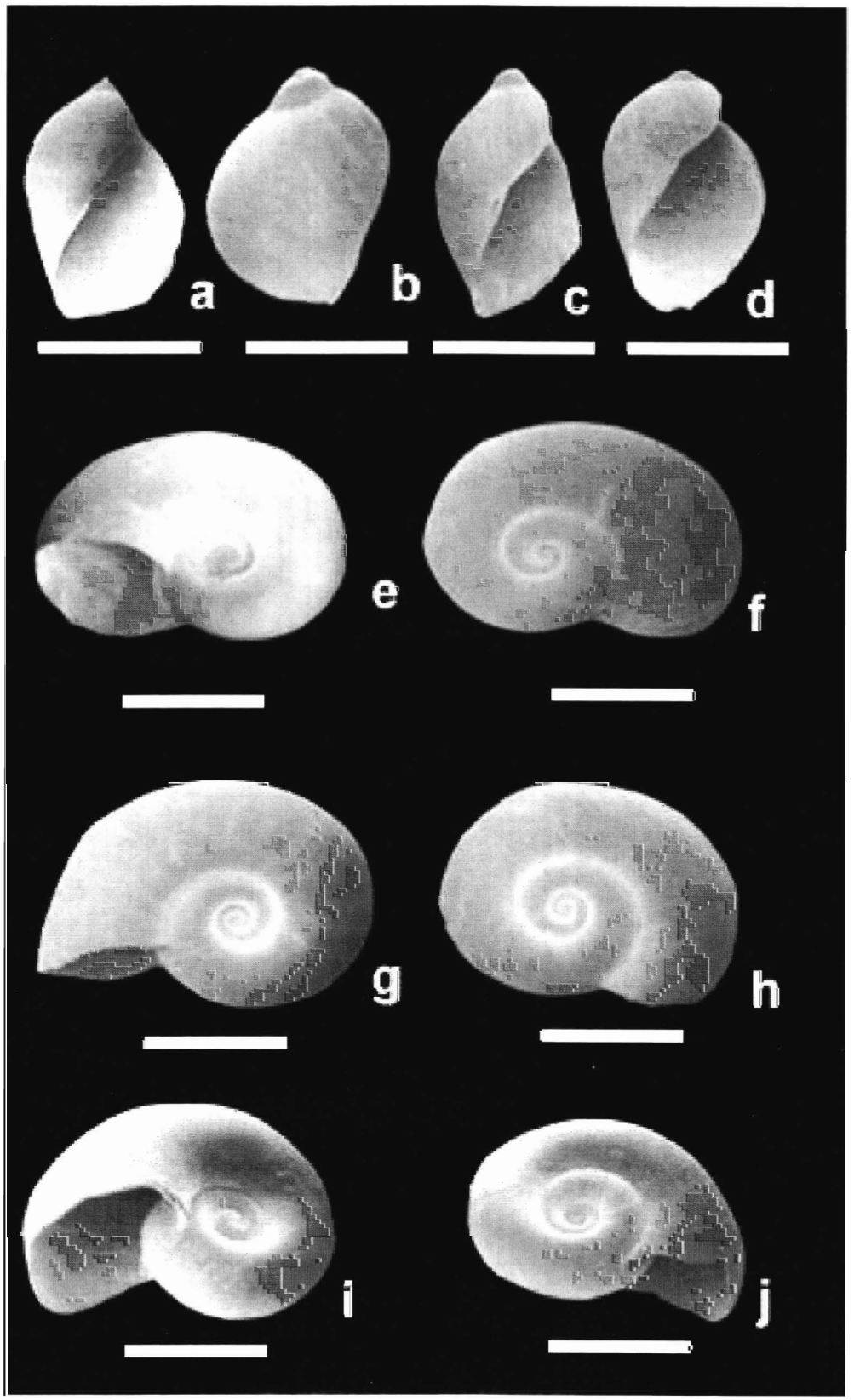
Description: Shell is small, globose, narrowly umblicate. It is made up of 3-4 whorls. Apex is rounded and shell is holostomatous and dextral. Sutures are not deeply incised and are horizontal. Spiral angle is 85^0. The body whorl is swollen and is more than ¾th of the entire shell length. The surface

EXPLANATION OF PLATE II

(Bar scale 1mm)

a-b (NAR/2022, 2037), ***Succinea indica*** Pfeiffer
c-d (NAR/102, 105), ***Succinea*** sp.;
e-f (NAR/404, 410), ***Gyraulus convexiusculus*** Hutton
g-h (NAR/523, 539), ***Gyraulus stewarti*** Germain;
i-j (NAR/ 811, 825), ***Gyraulus singularis*** Clenin

Plate II



of the shell is finely striated with axial ornamentation. Shell dimensions are given in Table 2.

Remarks: This species is smaller than the one reported by Bhatia and Mathur (1973) from the Upper Siwalik of Panjab. Siwalik forms have more bulbous body whorl compared to the present specimens.

Superfamily **Cerithiodea** Ferussac, 1819
Family **Thiaridae** Troschel, 1857
Genus ***Melanoides*** Oliver, 1807
Melanoides tuberculata Müller, 1774
(Pl. I, figs. r-s)

Nerita tuberculata Müller, 1774, p. 191
Melanoides tuberculatus (Müller) Prashad, 1921, p. 224-225
Melanoides tuberculatus (Müller) Brown, 1965, p. 46
Melanoides tuberculatus (Müller) Bentham Jutting, 1966, p. 412-418, text figs. 69, 73
Melanoides tuberculata (Müller) Bhatia and Mathur, 1973 p. 44-46, fig 6: 10-14
Melanoides cf. *Melanoides tuberculata* Gurung, 1998, p. 17, fig. 6(8-9)

Referred material: NAR/200-235 (Bhedaghat); NAR/236-250 (Devakachar), all complete shells and several broken shells.

Description: The shell seems to be multispiral with the spire ranging from 6 whorls in the juvenile specimens to 9-10 in the adult. The spire is much longer than the body whorl. The sutures between the whorls are well marked and are more or less horizontal. The shell is highly ornamented. Both axial and spiral ornamentation is present in the form of thick costae. Horizontal growth lines are also present. The body whorl is globose with a well-rounded base. The aperture is oval and holostomatous. The shell is dextral in orientation. The spiral angle is 32^0. Shell dimensions are given in Table 2.

Remarks: This species has a wide distribution and is known from the Ethiopian, Palearctic and Oriental regions (Bhatia and Mathur, 1973). It is found near river banks avoiding strong currents browsing on algal films that cover boulders and pebbles (Bandel and Reidel, 1998). This species has also been reported from the late Neogene Siwalik of Nepal (Gurung, 1998).

Family **Succineidae**
Subfamily **Succineinae**
Genus ***Succinea*** Draparnaud, 1801
Succinea indica Pfeiffer, 1849
(Pl. II, figs. a-b)

Succinea indica Pfeiffer, 1849, p.133
Succinea indica (Pfeiffer) Annandale, 1918, p. 105
Succinea indica Rao, 1924, p. 378-382, pl. 28, figs. 4-9
Succinea indica Prashad, 1937, p. 273-274
Succinea indica Bhatia, 1974, p. 390, fig. 3 (Q-R)

Referred material: NAR/2001-2005 (Bhedaghat); NAR/2026-2050 (Devakachar), all complete shells and a few broken shells.

Description: The shell is paucispiral with a short spire and a large body whorl. Aperture is larger and broader than the body whorl. Spiral angle is 55^0 to 60^0. The apex is moderately rounded. The sutures are inclined. Axial ornamentation can be seen on the surface. The aperture is holostomatous, large, dextral in orientation and bulges laterally. The callus is thin. The outer and the inner lips of the aperture are distinct in some specimens. Shell dimensions are given in Table 2.

Remarks: This is a widely distributed Oriental species which is also found in the Ethiopian region. The species has been reported from the Plio- Pleistocene and Recent of Java (Benthem Jutting, 1956). It has also been reported from Kashmir (Bhatia, 1974). Shells reported by Bhatia (1974) are bigger in size with more inclined sutures and a very acute apex angle compared to the Narmada forms.

Succinea sp. Draparnaud, 1801
(Pl. II, figs. c-d)

1973, *Succinea* sp. indet. Bhatia and Mathur p. 52-53, fig. 5(8)
1999, *Succinea* sp. indet. Mathur and Kotlia p. 176-177, figs. 5-7. Pl. 1, figs., 3-4.

Referred material: NAR/101-110 (Bhedaghat); NAR/111-125 (Devakachar), complete and some broken shells.

Description: The shell is ovoid and paucispiral with a large body whorl. The apex is rounded. Spiral angle is 70^0. The surface is finely striated. The body whorl has a wide oval aperture and a rounded base. The aperture is broader and larger than the body whorl. It is dextral in orientation and holostomatous. Thin callus is deposited on the inner lip of the peristome. Shell dimensions are given in Table 2.

Remarks: This is a semi-aquatic species found in the Himalaya and is known from Kumaun, Kashmir and Punjab (Annandale, 1918 ; Prashad 1937; Bhatia and Mathur, 1973; Bhatia, 1974). The present specimens are larger than the Siwalik forms (Bhatia and Mathur, 1973) which have a length of 1.5 mm and a width of 0.89 mm. The Narmada forms are also larger than the Ladakh forms (Mathur and Kotlia, 1999) which have a length of 1.01 mm and a width of 0.66 mm.

Superfamily **Planorboidea** Rafinesque, 1815
Family **Planorbidae** Rafinesque, 1815
Subfamily **Planorbinae** Rafinesque, 1815
Genus ***Gyraulus*** Agassiz, 1837
Gyraulus convexiusculus Hutton, 1849
(Pl. II, figs. e-f; Pl. IV, figs. j-l)

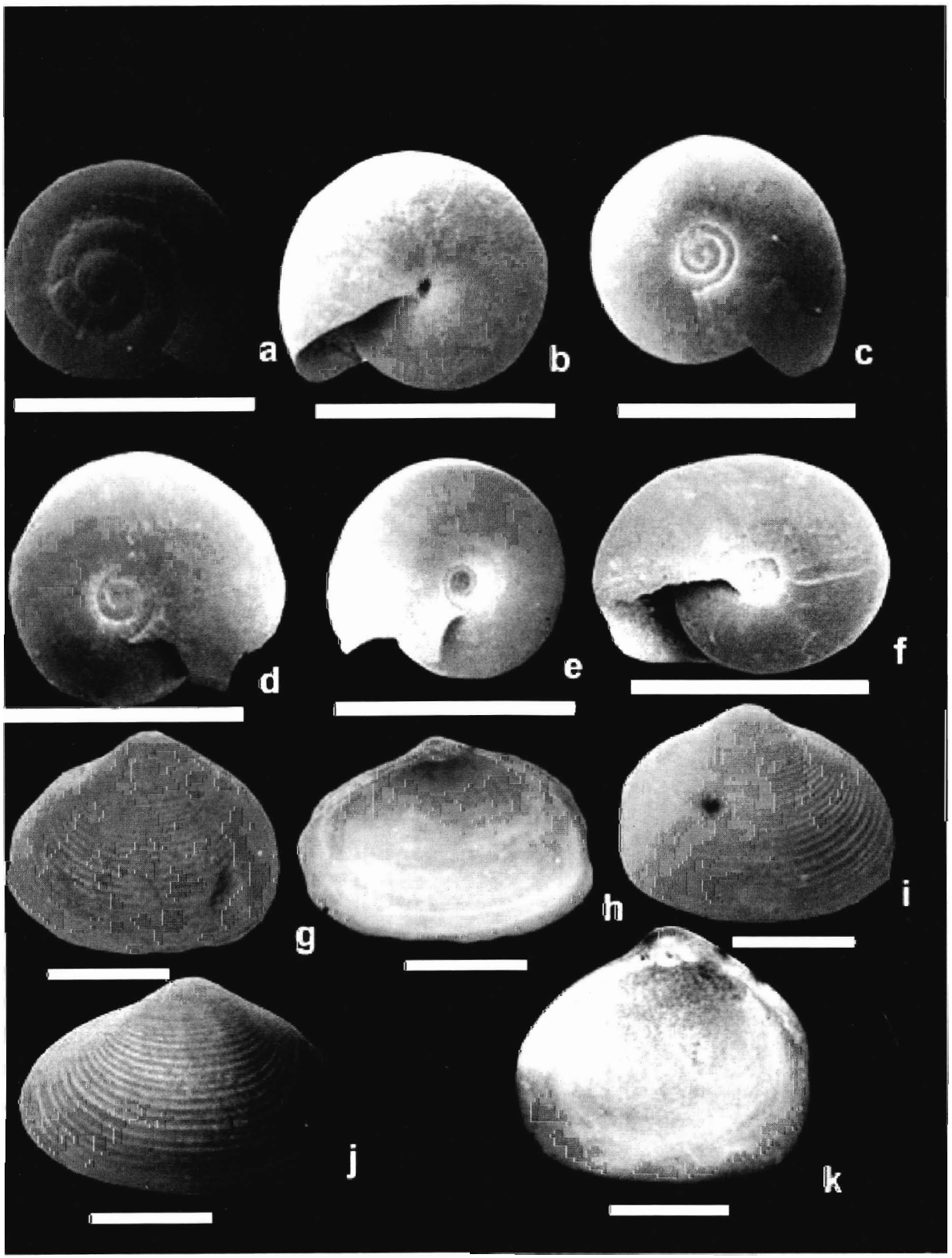
Planorbis convexiusculus Hutton, 1849, p. 657
Planorbis convexiusculus (Hutton) Annandale and Prashad, 1919, p. 54
Planorbis convexiusculus (Hutton) Annandale, 1921, p. 148
Planorbis (Gyraulus) convexiusculus (Hutton) Germain, 1922, p.118-119
Planorbis convexiusculus (Hutton) Prashad, 1922, p. 15
Planorbis convexiusculus (Hutton) Rao, 1928, p. 457
Planorbis convexiusculus (Hutton) Rao, 1929, p. 297
Planorbis convexiusculus (Hutton) Prashad, 1937, p. 279
Anisus convexiusculus (Hutton) Butot, 1955, p. 112. fig. 22
Gyraulus convexiusculus (Hutton) Benthem Jutting, 1956, p. 463-466, figs. 129- 130
Gyraulus convexiusculus (Hutton) Wright, 1963, p. 261, pl. 1, figs. 9-17
Gyraulus convexiusculus (Hutton) Bhatia and Mathur, 1973, p. 54, fig. 4 (8-9)
Gyraulus convexiusculus (Hutton) Bhatia, 1974, p. 371-395, fig. 2k
Gyraulus convexiusculus (Hutton) Mathur and Kotlia, 1999, p. 177-178, fig. 8

EXPLANATION OF PLATE III

(Bar scale 1mm)

a-b (NAR/724), ***Planorbis narmadaensis*** n. sp. ;
c-d (NAR/10, 26), ***Helicorbis*** sp.;
e-f (NAR/ 741, 742), ***Polypylis kennardi*** Bullen;
g-k (NAR/ 3001,3002,3025,3076,3080), ***Pisidium mitchelli*** Prashad.

Plate III



Referred material: NAR/401-415 (Bhedaghat); NAR/416-445 (Devakachar), all complete shells and a few slightly broken shells.

Description: The shell is small and coiled planispirally with two and a half to three gradually opening out whorls. The inner whorls are tightly coiled, while the outer ones are less embracing. The basal side of the specimens is convex with the penultimate whorl raised above the body whorl. The sutures are deeply incised. The surface is finely striated. The specimens are concave in the apical view. The umbilicus is moderately wide. The spire is clearly visible basally as well as in the apical view. The inner margin of the peristome is arched near the umbilicus. Shell dimensions are given in Table 3.

Remarks: This species is widely distributed throughout the oriental region (Bhatia and Mathur, 1973). In India, it has been reported from Kangra, Simla, Ambala, Manbhum (Orissa), Calcutta and the Andaman islands. It is also known from Mesopotamia, Afghanistan, China, Burma, Shan Plateau (Bhatia and Mathur, 1973) and Ethiopian region (Bhatia, 1974). From India, it has been reported from the Panjab Siwalik (Bhatia and Mathur, 1973), Pleistocene of Kashmir (Bhatia 1974) and Ladakh Himalaya (Mathur and Kotlia, 1999).

Genus **Gyraulus**

Gyraulus stewarti Germain, 1909

(Pl. II, figs. g-h; Pl. IV, figs. m-o)

Gyraulus stewarti Germain, 1909, p. 119

Planorbis (Gyraulus) stewarti Germain, 1922, p. 25

Gyraulus stewarti Bhatia and Mathur, 1973, p. 236-237, fig.4(10, a-b)

Referred material: NAR/501-530 (Bhedaghat); NAR/531-545 (Devakachar), all complete shells and several broken shells.

Description: The shell is small, planispirally coiled, trapezoid in the lateral outline and flat in the basal as well as in the apical view. The inner whorls are depressed in the apical view. There are 3 to 3 $^{1/2}$ whorls. The sutures are well incised. The inner whorls are tightly coiled while the outer ones are loosely coiled. Longitudinal striations are seen on the outer surface of the shell. The outer margin of the body whorl is sharp. The aperture is broad. Shell dimensions are given in table 3.

Remarks: This species has earlier been reported from the Panjab Siwaliks (Bhatia and Mathur, 1973). The Narmada forms are bigger than the Siwalik forms which have a maximum diameter of 1.6 mm and a minimum diameter of 1.5 mm.

Gyraulus singularis Clenin, 1886

(Pl. II, figs. i-j; Pl. IV, figs. p-r)

Planorbis singularis Clenin, 1876, p. 149, fig. 6

Planorbis singularis Nevill, 1878, p. 247, no. 57

Planorbis (Gyraulus) singularis (Mousson) Germain, 1923, p. 146-147, pl. 4, figs. 15-16

Planorbis (Gyraulus) singularis Bhatia and Mathur, 1971, p. 280-285, pl. 1, fig. 8

Planorbis (Gyraulus) singularis Bhatia and Mathur, 1973, p. 54 fig. 4 (14-16)

Referred material: NAR/801-825 (Bhedaghat); NAR/826-850 (Devakachar), all complete shells and a few broken shells.

Table 3: Measurements of planispiral gastropod shells and bivalvies.

Species	Mean diameter d1 (including aperture) mm	Mean diameter d2 (excluding aperture) mm
Gyraulus convexiusculus (n=45)	3.93	3.35
Gyraulus stewarti (n=45)	4.23	3.66
Gyraulus singularis (n= 50)	2.64	2.2
Planorbis narmadaensis n. sp (n=17)	1.14	0.97
Helicorbis sp. (n=50)	2.35	2.08
Polypylis kennardi (n= 06)	1.49	1.3
Pisidium mitchelli (n=100)	4.27	5.09

Description: The shell is planispirally coiled and small in size. The number of whorls are 2-2 $^{1/2}$. The aperture is high, crescentric. Longitudinal striations are seen on the surface of the shell. The apical side of the shell is flat with depressed and tightly coiled inner whorls. The outer whorls are less embracing. The aperture is rounded showing acute basal periphery. Shell dimensions are given in Table 3.

Remarks: This is a widely distributed species. In India, it was reported from the Panjab Siwalik (Bhatia and Mathur 1973).

Family **Planorbidae** Rafinesque, 1815

Subfamily **Planorbinae** Rafinesque, 1815

Genus ***Planorbis*** Müller, 1774

Planorbis narmadaensis n. sp.

(Pl. III, figs. a-b; Pl. IV, figs. g-i)

Derivation of name: Named after river Narmada, the major river of the study area.

Holotype: NAR/724, a complete shell.

Paratypes: NAR/720,730,731, all complete shells.

Type locality: Bhedaghat, 12 km southwest of Jabalpur (M.P.); Devakachar, 120 km southwest of Jabalpur (M.P.).

Horizon and age: Medium to coarse-grained sand. The horizon is Middle to Upper Pleistocene.

Diagnosis: Shell small, planispirally coiled, sutures superficial.

Description: The shell is very small and planispirally coiled. The number of whorls range from 1 $^{1/2}$ to 2. The shell is flat in apical view. The umbilicus is visible in the basal view. The aperture is oval. The sutures are not deeply incised and appear to be superficial, thereby giving the specimens a characteristic appearance. The ornamentation is in the form of fine striations. Shell dimensions are given in Table 3.

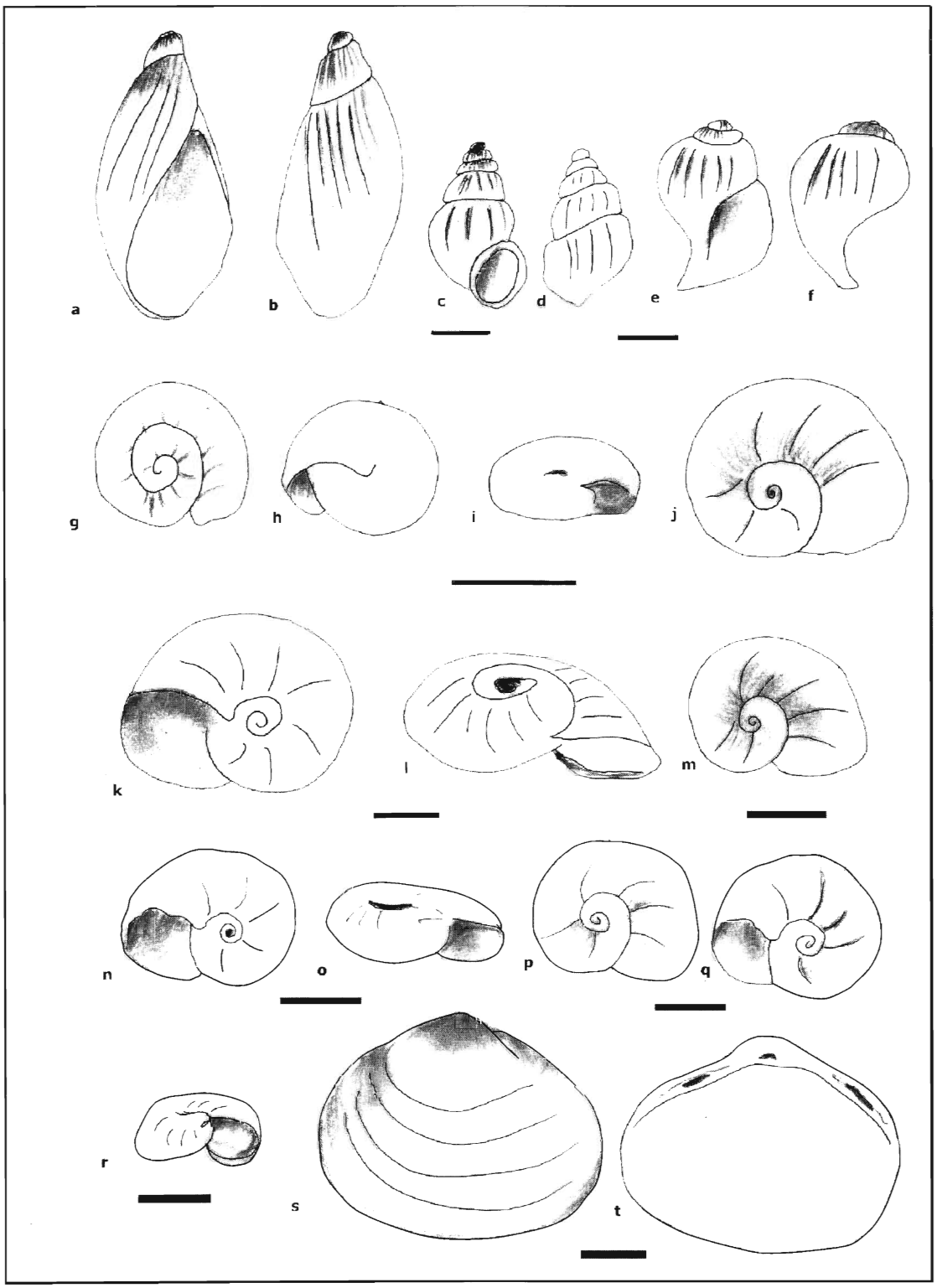
Remarks: The present species is similar to *Gyraulus convexiusculus, Gyraulus stewarti, Gyraulus singularis, Planorbis planorbis tangitarensis and Indoplanorbis exustus* (Bhatia and Mathur, 1973; Bhatia, 1974) in having a planispiral shell but differs from them in having a much smaller size and superficial sutures. The Narmada forms have a constricted

EXPLANATION OF PLATE IV

(Bar scale 1mm)

a-b ***Lymnaeo theobaldi*** n. sp.
c-d ***Tricula bhatiai*** n. sp.
e-f ***Digoniostoma annandalei*** n. sp.
g-i ***Planorbis narmadaensis*** n. sp.
j-l ***Gyraulus convexiusculus*** Hutton;
m-o ***Gyraulus*** **stewarti** Germain;
p-r ***Gyraulus*** **singularis** Clenin;
s-t ***Pisidium*** **mitchelli** Prashad.

Plate IV



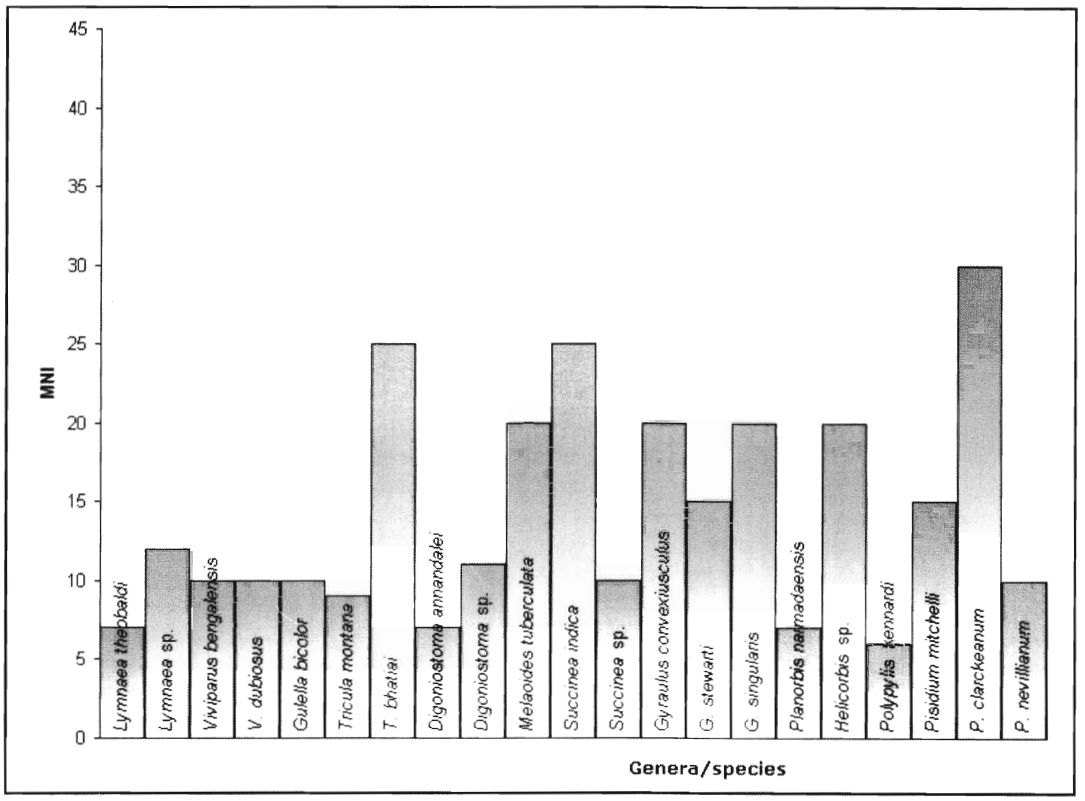


Fig. 2. Minimum number of individuals (MNI), genera and species in the Bhedaghat section.

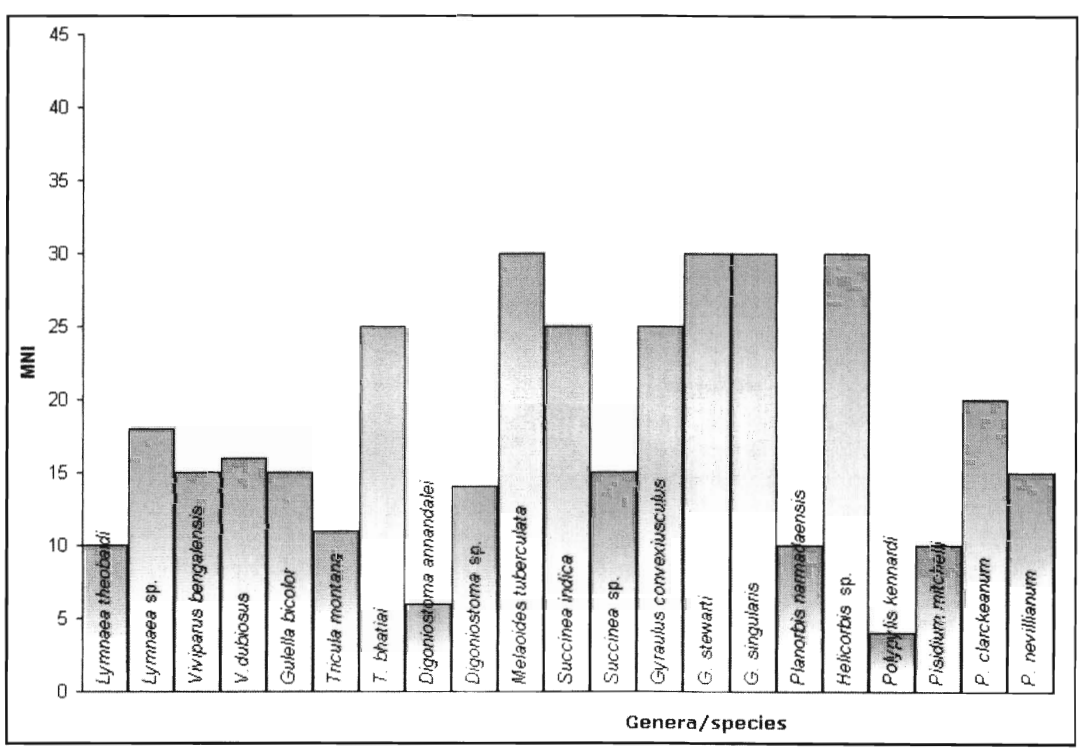


Fig. 3. Minimum number of individuals (MNI), genera and species in the Devakachar section.

aperture, whereas all the other species have a much more distinct aperture. Narmada forms have 1-2 spiral whorls, whereas the other species have a minimum of $2^{1/2}$ to 3 whorls. In the present shells, the umbilicus is seen only in the basal view, while in the other forms it is seen in both the views.

Genus ***Helicorbis*** Benson, 1855

Helicorbis sp.

(Pl.III, figs. c-d)

Helicorbis sp. Bhatia and Mathur, 1973, p. 55-56, fig. 4 (21, a- b)

Referred material: NAR/1-27 (Bhedaghat); NAR/28-50

(Devakachar), all complete shells and some broken shells.

Dercription: The shell is small, planispirally coiled, concave to flat in the apical view. The spire is clearly visible apically but only partly visible in the basal view. The umbilicus is moderately wide. There are 2 to 2½ rapidly opening whorls. The sides of the ultimate whorl are steeply sloping. The shell surface is finely striated. Shell dimensions are given in Table 3.

Remarks: This species was earlier reported from the Upper Siwalik of Panjab (Bhatia and Mathur 1973). The Narmada forms are much larger than the Siwalik forms.

Genus ***Polypylis***

Polypylis kennardi Bullen, 1906

(Pl. III, figs. e-f)

Segmentina calathus Martens, 1897, p. 15

Polypylis kennardi Bullen, 1906, p. 130

Polypylis kennardi (Bullen) Benthem Jutting, 1956, p. 468-469, figs. 125, 132,133

Polypylis sp cf. *Polypylis kennardi* Bhatia and Mathur, 1973, p. 55, fig. 4(18-20 a, b)

Referred material: NAR/741-746 (Devakachar), nearly complete and a few broken shells.

Description: The shell is planispirally coiled. The inner whorls are tightly coiled while the outer ones are loose. The specimens show acute basal periphery. The umbilicus is closed in the basal view. Shell dimensions are given in Table 3.

Remarks: This species is smaller than the one reported by Bhatia and Mathur (1973) from the Upper Siwalik of Panjab.

Phylum **Mollusca**

Class **Pelecypoda**

Family **Pisididae**

Genus ***Pisidium*** Pfeiffer, 1821

Pisidium mitchelli Prashad, 1925

(Pl. III, figs. g-k; Pl. IV, figs. s-t)

Pisidium mitchelli Prashad, 1925, p. 419-420, pl. 7, figs. 11, 11a; pl. 8, fig. 10

Pisidium mitchelli Bhatia and Mathur, 1973, p. 24-58, fig. 3(8a-b), fig. 4 (5-7), fig. 9 (1-5)

Pisidium mitchelli Bhatia, 1974, p. 371-395, fig. 2

Pisidium mitchelli Mathur and Kotlia, 1999, p. 173-180, Plate 1, fig. 2, Fig. 4

Referred material: NAR/3001-3010 (Bhedaghat); NAR/3011-3025 (Devakachar), all complete shells and a few broken shells.

Description: The shell is medium in size, moderately thick and inequilateral. The external margin of the hinge is strongly curved, while the internal margin is gently curved. The umbo is placed posterior to the margin and does not project over the hinge. The external surface has fine concentric growth lines. The hinge is almost half the length of the shell and is gently sloping. It is very thin in the posterodorsal region. One cardinal tooth and two sockets can be seen just below the umbo in the right valve. The anterior region is flared up. The ventral margin is gradually arched, while the dorsal margin is strongly arched. Shell dimensions are given in Table 3.

Remarks: This species has been reported from the Upper Siwalik of Panjab (Bhatia and Mathur, 1973). The specimens reported from the Narmada valley are similar to the Siwalik forms in having a strongly curved hinge line and similar surface ornamentation. However, the Narmada forms are much larger than those reported from the Siwalik which have a mean height of 1.5 mm and length of 1.6 mm. *Pisidium mitchelli* of Narmada valley is similar to *Pisidium hydaspicola* (Bhatia, 1974) in the general outline but differs from it in having a larger size and a feeble hinge line. The present forms are similar to *Pisidium clarckeanum* in the overall shape and the position of the umbo relative to the hinge but are much larger with a thicker shell and a much more prominent umbo. They also have a weaker hinge and a less prominent umbo than *Pisidium nevillianum*. Compared to *Pisidium sivalensis,* the present species is much larger in size and has a much strongly curved hinge line. *P. mitchelli* has also been reported from the Ladakh Himalaya (Mathur and Kotlia, 1999). However, the Ladakh specimens are smaller compared to the Narmada specimens but have a stronger hinge line. The present species is different from *Pisidium* sp. (Mathur and Kotlia, 1999) in having a weaker hinge line and a more ornamented external surface.

PALAEOECOLOGICAL INTERPRETATION

Most abundant invertebrate remains from both the sections belong to the gastropods. In order to carry out the taxonomic abundance, minimum number of individuals (MNI) per taxon was used (Figs. 2, 3). The MNI is necessary to account for the identified specimen of a taxon (Lyman, 1994; Lyman *et al.*, 2003). The fossil remains show similarity in both the sections (see Figs. 2, 3). The fossil elements in the collection resemble their living counterparts. Palaeoecological conclusions are drawn on the basis of the principle of actualism. These may be speculative as the type of conditions, i.e. community structure, competition, spatial heterogeneity and physical barriers which confine a given taxon to certain geographical range may not have existed in the past.

Since this is the first report of invertebrate remains from the study sites, an attempt was made to reconstruct the palaeoecology and palaeocommunity structure around the Narmada valley. On the basis of faunal assemblages, the pond community seems to constitute the most dominant habitat. Such a community with abundant gastropods and pelecypods has also been described from the Miocene Siwalik of Kashmir (Gaur and Chopra, 1983), Saketi Siwalik (Patnaik, 1995), Kashmir (Bhatia, 1974) and Kashmir Karewas (Kotlia, 1989). The present suite of molluscs indicates the habitat ranging from terrestrial through semi-aquatic to aquatic (Kotlia *et al.*, 1998; Joshi, 2003). They can survive in adverse conditions as they are able to breathe through lungs as well as gills. *Gulella bicolor* is a terrestrial taxon which is a carnivorous species found living amongst decaying wood and damp places (Benthem Jutting, 1950; Joshi, 2003). *Succinea* is a semi-aquatic taxon which is known to occur at the edge of water but does not lead a truly aquatic life (Annandale, 1918). *Gyraulus* and *Planorbis* can live in ponds, lakes as well as muddy bottoms of water channels (Annandale and Prashad, 1919; Prashad, 1937; Mathur and Kotlia, 1999). *Melanoides*, a bottom dweller is found in shallow pools with a rocky substratum (Bhatia and Mathur, 1971), whereas *Viviparus* lives on sediment surface and aquatic plants (Bhatia and Mathur, 1973). *Lymnaea* is a typical running water taxon (Annandale and Prashad, 1919; Kotlia *et al.*, 1998; Mathur and Kotlia, 1999). *Pisidium* is indicative of a typical lacustrine community (Bhatia, 1974; Kotlia *et al.*, 1998; Mathur and Kotlia 1999). It thrives in pools, ponds, streams and lakes. It can thrive in habitats that are almost anorexic for a period of time such as the profundal areas of lakes.

Apart from invertebrates, the Narmada valley has yielded a diverse assemblage of microvertebrates including fish, lizards and small mammals (Kotlia and Joshi, 2008). The recovered

microfaunal assemblage indicates a warm tropical climate persisting in Narmada valley during the late Pleistocene. The micromammalian remains have been found to be impregnated with iron which points towards subaerial exposure in warm humid climatic conditions (Kotlia and Joshi, 2008). Fish such as *Cyprinus* is known to thrive in warm tropical climatic conditions. The megavertebrates, e.g. *Cervus* (Lydekker, 1885), *Bos* (Lydekker, 1886; Pilgrim, 1939), *Elephas* (Pilgrim, 1905; Tripathi and Basu, 1983), *Equus* (Biswas, 1988; Biswas *et al.,* 2005), discovered from this region also testify to the prevalence of warm tropical climatic conditions with seasonal pools developing away from the channel area in the Narmada valley.

However, fossil finds such as lizards and *Golunda* from the valley point at oscillations or small events of aridity in the region (Kotlia and Joshi, 2008; Joshi and Kotlia, 2010). This observation is further strengthened by the work of Biswas (1997) who reported the extinction of some vertebrates in the fossiliferous horizons of the upper part of the Narmada sequence because of minor arid oscillations in an otherwise warm and humid climate.

CONCLUSIONS

Eighteen species of freshwater gastropods and one species of bivalves indicate that a river, stream or a similar freshwater body existed in the Narmada valley during the late Pleistocene times. The Narmada valley seems to have provided a favourble climate to the animals which had migrated from the northwest because of the harsh climatic conditions in the glacial period of the early Pleistocene. The climatic conditions during the deposition of *H. erectus* (Surajkund Formation) and our fossil material (Hirdepur Formation) remained mainly warm and humid except for minor spikes of arid oscillations as has been indicated above. Presently, the Narmada landmass comprises temperate/sub-tropical setting, dominated by seasonal monsoon regime and thus the climatic fluctuations (cooling and drying periods, particularly based on the microvertebrate fossils) have influenced the fauna and flora of the basin.

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ANNOUNCEMENT

A Humboldt Kolleg and International Conference with a focal theme of "Earth Resources for Future Sustenance" is being organized by the Periyar University, Salem during 7-9th September 2011. Objective of this event is to provide a platform for Humboldtians and leading scientists and potential future scientists – students to conduct cutting-edge research in collaboration with German academic and research institutions. Deadline for submission of abstracts and registration is 15.05.2011. Best paper awards are proposed to be given to young researchers who are below 35 years old. For detailed information, themes and subthemes, program schedule, registration form, etc., visit the website www.earth-future.org or contact Dr. Mu.Ramkumar, Convener, Earth-Future, Room No.155, Department of Geology, Periyar University, Salem – 636011 or email to convener@earth-future.org.