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Middle Siwalik Charophyta from Mohand area, Dehradun Sub-Basin, NW Himalaya, India

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This paper describes a taxonomically diverse assemblage of charophytes recovered from the Middle Siwalik strata of Mohand area, Dehradun sub-basin, NW Himalaya. Recovered from a horizon dated ~9 Ma, early late Miocene, the collection comprises 13 species belonging to 7 genera: *Chara aspera, Chara globularis, Chara rantziene, Chara* sp.*, Hornichara maslovi, Lychnothamnus breviotus, Nitellopsis megarensis, Nitellopsis tectochara merianii, Nitellopsis tectochara haungii, Sphaerochara tewarii*, *Lychnothamnus barbatus, Lychnothamnus* sp. and *Lamprothamnium papulosum*. Associated fossils include freshwater ostracods, gastropods and fishes. Palaeoecological considerations of the recovered charophyte assemblage suggest a shallow, warm, low energy, semi-permanent to permanent lake or pond.

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INTRODUCTION

The Siwalik succession comprises a thick pile of about 6000 m mudstone, sandstone and conglomerate which was deposited by a fluvial system in the foreland basin along the southern edge of the evolving Himalaya and now comprising Outer Himalaya/Sub-Himalaya (Kumar and Tandon, 1985 a, b; Prakash *et al*., 1980). These molasse deposits are widely considered to be excellent archives for Neogene and Quaternary biota and continue to provide extremely valuable insights into the Neogene orogenic evolution of the Himalaya besides the paleoecologic, paleoclimatic and paleobiogeographic evolution during this period (e.g. Bajpai *et al*., 2020).

Compared to other fossil groups, records of Siwalik Charophyta are scarce, and only a few sporadic occurrences have been reported (Tewari and Sharma,1972; Bhatia and Mathur, 1978; Bhatia, 1999; Sharma *et al*., 2015). Here we describe a diverse assemblage of charophytes for the first time from the Middle Siwalik strata of the Mohand section. The assemblage was found in association with freshwater gastropods, ostracods and fish remains. The palaeoecological implications of the charophyte assemblage are also discussed.

STUDY AREA

The Mohand Range is present on the southern side of the Dehradun re-entrant and is separated by Lesser Himalaya by the Doon valley. It exposes the Middle and Upper Siwalik sediments deposited mainly by braided rivers, and the succession consists of sandstone-mudstone, sandstone and conglomerate-sandstone (Kumar and Nanda, 198; Kumar 1993; Kumar *et al*. 2004) (Fig.1). A detailed geological account of the section is available in the excursion guides (Tandon *et al*., 1988; and Kumar *et al*., 1991). Magnetopolarity studies by Sangode *et al*. (1999) suggest an age from 9.73 Ma to 4.86 Ma (Late Miocene - Early Pliocene). Kumaravel

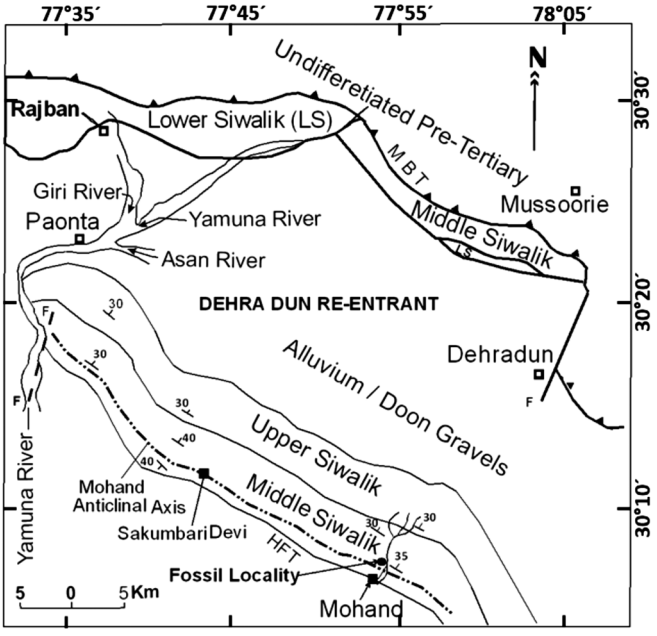


Fig. 1. Geological map of Siwalik Group in the Sub-Himalaya of Mohand-Dehradun area showing fossil locality

et al. (2005), based on rock magnetic studies in this section, broadly inferred the prevalence of a semi-humid to semi-arid climate.

Although the Mohand area is geologically well studied, paleontologically it remains poorly explored. Bhandari and Tiwari (2003) mentioned the presence of several ostracod taxa (*Cyclocypris, Candona, Cypridopsis* and *Candonopsis*) along with fishes from this area. However, it was the discovery of a murid rodent (*Parapodemus*) that brought the Mohand area in to focus (Tiwari and Bhandari, 2014). Fresh water gastropods (*Plotia* cf. *P. scabra, Gyraulus* sp. and *Lymnaea* sp.) were also reported from the same general locality by Bhandari *et al*. (2014). No other fossils are known from this section.

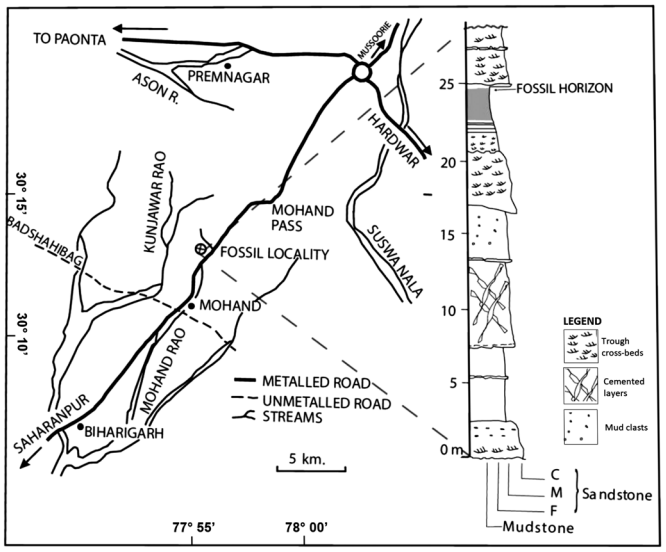


Fig. 2. Fossil locality and its litholog showing charophyte-yielding horizon in Mohand-Dehradun area, NW Himalaya

The present charophyte-yielding locality is situated around 21 km towards Mohand from Dehradun, on the right bank of the Mohand Rao (stream), along the Dehradun-Saharanpur road, District Saharanpur, Uttar Pradesh (Fig.2). The bulk samples were collected from three closely located sites whose coordinates are as follows: 30°12'36.3"N and 77°55'05.2"E; 30° 12'33.66"N and 77°55'05.22"E and 30°12'34.83"N and 77°55'5.11"E. The charophyte-yielding horizon lies near the top of a fining upward interlude in the Middle Siwalik succession, and consists of a dark grey mudstone usually up to 10 cm thick (see details of this section in Fig. 2 of Tiwari and Bhandari, 2014; see also Bhandari *et al*., 2014). Paleomagnetic studies place this horizon at ~1100 m. The same horizon is also known to yield a murid rodent (*Parapodemus*) assigned to 9.2 Ma age (Tiwari and Bhandari, 2014). Thus, the best current age assessment of the charohytes reported here is 9.2 Ma. A second, younger charophyte-yielding horizon occurs in the same section about 500m upstream at a stratigraphic level estimated in age to be ~5 Ma, i.e. close to the Miocene-Pliocene boundary (Kumar et al. 2004).

MATERIAL AND METHODS

The charophyte-yielding mudstone samples were collected from the Middle Siwalik subgroup which is exposed along the Mohand Rao stream. Bulk samples, broken to small pieces, were first dried under the sun for 3 days to set them free from moisture. The dried up samples were soaked in kerosene for about 4 hours, and then transferred to submerge in water. This led to complete disintegration of samples and the formation of a slurry which was then passed through the running water with a set of sieves of different sized meshes (10, 30, 40, 60 ASTM). The residue of each sieve was then dried and collected to scan under a binocular microscope for picking charophytes and other associated microfossils. This was followed by their Scanning Electron Micrography (SEM). Charophytes were recovered from the +40 and +60 mesh residues.

All specimens described and figured here are catalogued as BSIP41931-BSIP41935 numbers in Birbal Sahni Institute of Palaeosciences.

The abbreviations used in the descriptions and in the table are as follows:

LPA: length of the polar axis of the gyrogonite.

LED: largest equatorial diameter of the gyrogonite.

AND: distance from the apical pole to the LED as calculated along the polar axis.

EA: equatorial axis

ISI: isopolarity index, i.e. 100* LPA/LED

ANI: anisopolarity index, i.e. 100* AND/LPA

Lsp: width of the lime spirals, measured between the intercellular sutures at the equatorial axis of the gyrogonite.

SYSTEMATICS

Division ***Charophyta***
Class ***Charophyceae***
Order ***Charales***
Family ***Characeae***
Subfamily ***Charoideae***
Genus ***Chara*** Linné, 1753

Chara globularis aspera (Deth. ex Willd.)Wood, 1962
(Pl. I, Figs. 1-3)

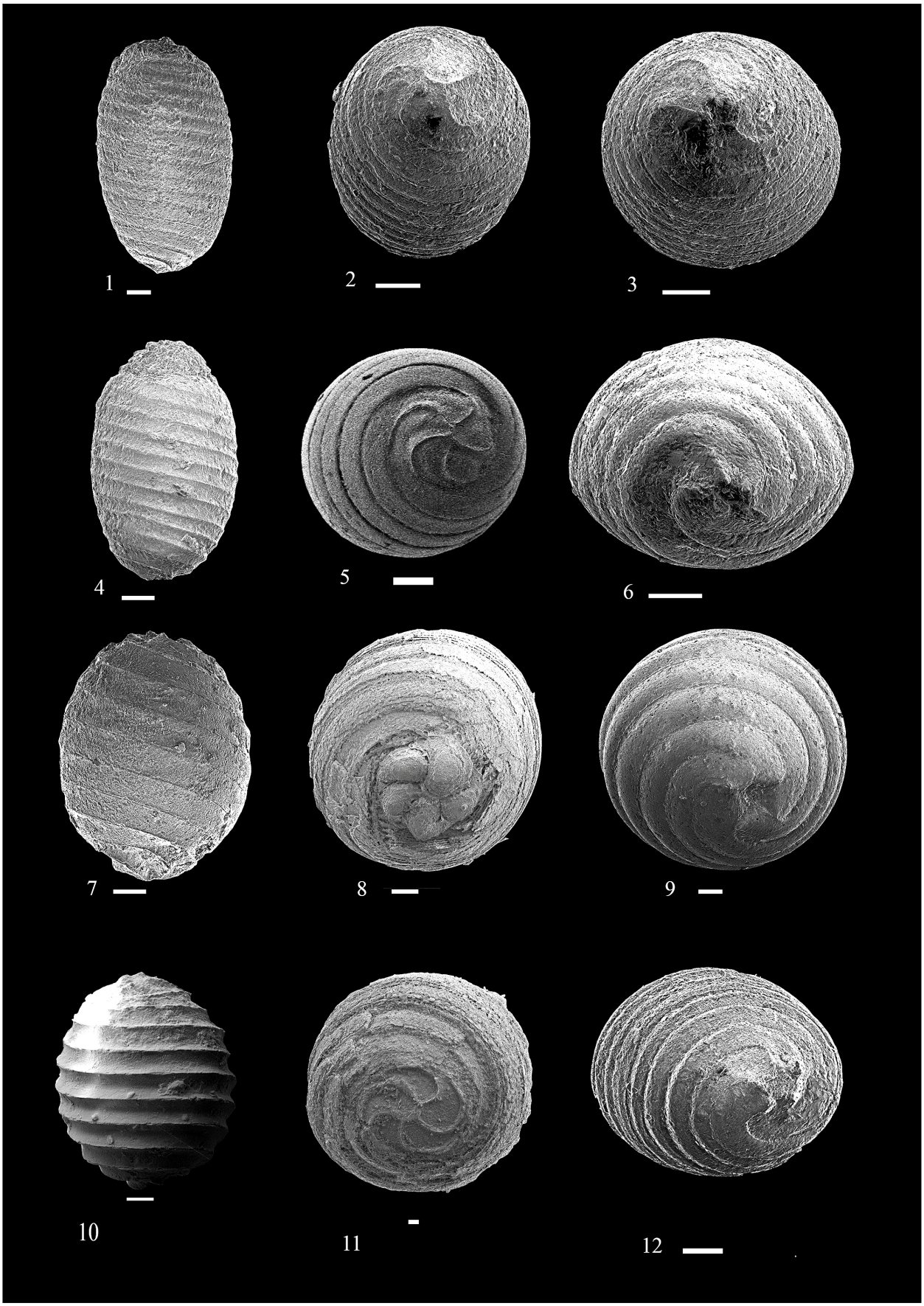
Referred specimens: BSIP41931/UB/NTC/101-103

Description: Lime shells prolate and ellipsoidal in shape with the apical pole rounded and the basal part truncate; lime spirals show around 14-16 convolutions, which become flat at the equator; apical junction is formed in a very short

PLATE I

Plate I: 1-3, *Chara aspera*: 1, lateral view; 2, apical view; 3, basal view. 4-6, *Chara globularis*: 4, lateral view, 5. apical view, 6. basal view.7-9, *Chara rantzieni*:7, lateral view; 8, apical view; 9, basal view. 10-12, *Chara* sp. indet.: 10, lateral view; 11, apical view; 12, basal view. Scale Bar = 100 µm.

Plate I



zigzagged line; basal pore with an outer opening and a distinct pentagonal shape, and surrounded by prolonged basal tips of the lime spirals.

Table 1. Measurements of *Chara globularis aspera*

C.No.	LPA (µm)	LED (µm)	AND (µm)	ISI (LPA/ LED* 100)	ANI (AND/ LPA* 100)	Lsp	No. of convolutions
BSIP 41931/ UB/NTC /101	862.2	535.5	442.3	161	51.2	55	16

Remarks: The present collection consists of over 125 gyrogonites of this subspecies. The range of variation in this subspecies is LPA 800-900; LED 525-600; Lsp 53-58. It represents the dioecious form of the monoecious *Chara globularis* (Proctor, 1980). Soulié-Märsche (1989) described its role as a lacustrine biomarker in North Africa during the Quaternary. Bhatia and Singh (1989) reported this taxon from the Quaternary marls of the Indo-Gangetic Plains and later also from the Tarot and Pinjor formations of Upper Siwalik (Bhatia, 1999).

Chara globularis globularis Thuillier,1799
(Pl. I, Figs. 4-6)

Referred specimens: BSIP41931/UB/NTC/104-106

Description: Lime shells sub prolate to prolate spheroidal in shape; apical portion of the gyrogonites rounded; basal portion subtruncated; apical periphery looks truncated when viewed laterally; 9-15 thick convex convolutions which become thinner towards the apical periphery; 5 spiral cells make a moderate spiral rosette joined by a zig zag line; basal pore circular to pentagonal in shape.

Table 2. Measurements of *Chara globularis globularis*

C. No.	LPA (µm)	LED (µm)	AND (µm)	ISI (LPA/ LED* 100)	ANI (AND/ LPA* 100)	Lsp (µm)	No. of Convolutions
BSIP 41931/ UB/NTC/ 104	635	435	306.8	145.9	48.3	53.4	14

Remarks: Nearly 175 gyrogonites in the present collection pertain to this subspecies. *Chara globularis* is an extant and cosmopolitan species with the following variation in dimensions: LPA 620-850; LED 420-600; Lsp 50-60. Tewari and Sharma (1972) previously described this species as *Chara indica*, while Bhatia and Mathur (1978) initially reported it as *Chara surajpurica.* Subsequently, Bhatia (1999) referred it to *Chara globularis globularis*.

Chara rantzieni (Tewari & Sharma, 1972) Bhatia & Mathur 1978
(Pl. I, Figs.7-9)

Referred specimens: BSIP41931/UB/NTC/107-109

Description: Gyrogonites small to medium-sized; shape prolate spheroidal to subprolate, ellipsoidal to subovoidal; apically rounded and sometimes subtruncate; basally mostly rounded; apical periphery somewhat truncated in the lateral view; 8-10, flat to convex, moderately thick to wide convolutions; moderately developed apical rosette present, joined along by a short zigzagged line; intercellular ridges seen in thinly calcified gyrogonites; basal pore cone-shaped, pentagonal to subcircular, without outer basal depressions; LPA 550-650: LED 450-500; Lsp 75-85.

Table 3. Measurements of *Chara rantzieni*

C.No.	LPA (µm)	LED (µm)	AND (µm)	ISI (LPA / LED* 100)	ANI (AND/ LPA * 100)	Lsp (µm)	No. of convolutions
BSIP 41931/ UB/ NTC/ 107	620	484	303.9	128	49	81.4	9

Remarks: This species is rather rare in the present collection (5 lime shells). It ranges in age from Pliocene to the Recent and is known from the Upper Siwaliks (Tatrot Formation) of India (Tewari and Sharma, 1972; Bhatia and Mathur, 1978; Bhatia,1999). The species has a characteristic well developed apical rosette, but the basal opening is similar to that of the genus *Chara*. *C. rantzieni* is considered to be correlative with *C. pappi* that was reported from the Pliocene of Greece and from the Quaternary of the Indo-Gangetic plain (Soulié-Märsche, 1979; Bhatia and Singh, 1989). *C. pappi* is considered to be as a younger equivalent of *C. rantzieni* (Bhatia, 1999).

Chara sp. indet.
(Pl. I, Figs 10-12)

Referred specimens: BSIP41931/UB/NTC/110-112

Description: Gyrogonites small to medium-sized: subprolate to prolate, rarely prolate spheroidal and ellipsoidal, rarely subovoidal; apically slightly protruding to broadly rounded; basally, broadly rounded; 9-11, moderately thick concave convolutions; apical cells wide and joined along a short straight line; basal pore pentagonal, wide and conical.

PLATE II →

Plate II: 1-3, *Hornichara maslovi:* 1, lateral view; 2, apical view; 3, basal view. 4-6, *Lychnothamnus breviotus*: 4, lateral view, 5. apical view, 6. basal view. 7-9, *Nitellopsis (Tectochara) megarensis*:7, lateral view; 8, apical view; 9, basal view. 10-12, *Nitellopsis (Tectochara) huangii*: 10, lateral view; 11, apical view; 12, basal view. Scale Bar = 100 µm.

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Plate II

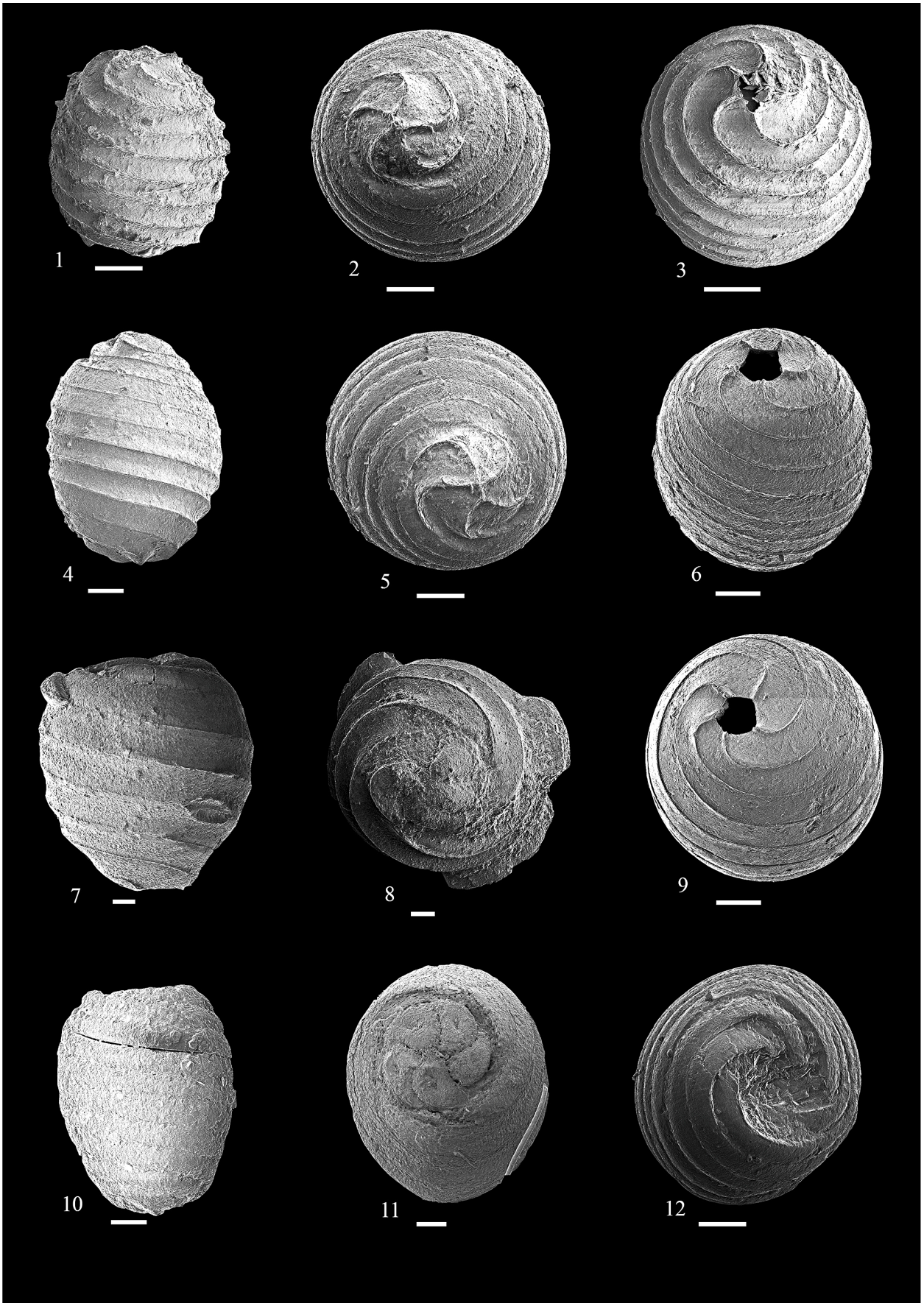


Table 4. Measurements of *Chara* sp. indet.

C.No.	LPA (µm)	LED (µm)	AND (µm)	ISI (LPA / LED *100)	ANI (AND / LPA * 100)	Lsp (µm)	No. of convolutions
BSIP 41931 / UB/ NTC/ 110	802.3	633.3	431.4	126.6	53	94	11

Remarks: Three gyrogonites in the collection are similar to those described as *Chara* sp. from the Upper Siwaliks by Bhatia and Mathur (1978). Additional specimens are needed for a precise identification. The specimens also bear some resemblance with *Charites angusta* described by Maslov (1966).

Genus ***Hornichara*** Maslov, 1963

Hornichara maslovi Bhatia and Mathur, 1978
(Pl.II, Figs. 1-3)

Referred specimens: BSIP41931/UB/NTC/113-115

Description: Gyrogonites small-sized, predominantly subprolate, and occassionaly prolate spheroidal and rarely prolate and ellipsoidal; apically broadly rounded; conically protruded at the base; 9-12 moderately wide, concave convolutions; intercellular ridges sharp; apical cells join at a point; basal pore pentagonal, moderately wide.

Table 5. Measurements of *Hornichara maslovi*

C. No.	LPA (µm)	LED (µm)	AND (µm)	ISI LPA /LED * 100	ANI AND / LPA * 100	Lsp (µm)	No. of convolutions
BSIP 41931 / UB / NTC / 113	447.1	368.2	245.8	121.4	54.9	49.4	11

Remarks: Over 10 gyrogonites in the present collection pertain to *Hornichara maslovi* which is being recorded for the first time from the Middle Siwaliks. Bhatia and Mathur (1978) described this species from the Upper Siwaliks (Pliocene). Its range of variation is as follows: LPA 400-650; LED 300-550; widths between the convolutions 48-51.

Genus ***Lychnothamnus*** (Ruprecht) A. Braun, 1856

Lychnothamnus breviotus Lu & Luo, 1990
(Pl. II, Figs. 4-6)

Referred specimens: BSIP41932/UB/NTC/116-118

Description: Oval-elongated gyrogonites of medium size; wide and generally flattened apex lacking apical nodules; basal funnel well developed, short; spiral cells smooth, broad and slightly concave to flat with 8–10 convolutions and a faintly developed double suture.

Table 6. Measurements of *Lychnothamnus breviotus*

C. No.	LPA (µm)	LED (µm)	AND (µm)	ISI (LPA / LED * 100)	ANI (AND / LPA* 100)	Lsp (µm)	No. of convolutions
BSIP 41932 / UB / NTC / 116	635.5	476.9	316.9	133.2	53.6	74	11

Remarks: More than 20 gyrogonites in the present collection are identified as *Lychnothamnus breviovatus*, a species which was first recorded from the Karewa deposits of Kashmir (Bhatia 1985), and was subsequently also reported from the Dhok Pathan and Pinjor formations of the Siwalik Group (Bhatia 1999). The species was considered to be rare in the Dhok Pathan Formation, but quite abundant in the Pinjor Formation (Bhatia, 1999). *L. breviovatus* was originally described from the Late Oligocene and Neogene deposits of Tarim Basin, Xinjiang, China (Lu and Luo, 1990). Known variation in the dimensions of this species are: LPA 510-650; LED 450-480; Lsp 65-75. Compared to the type species *L. barbatus,* L. *breviovatus* is ovoidal to nearly spheroidal and much smaller. The present record extends the geographic range of the species.

Lychnothamnus sp. indet.
(Pl. III, Figs. 4-6)

Referred specimens: BSIP41932/UB/NTC/119-121

Description: Gyrogonites subprolate and ellipsoidal to subovoidal; basally slightly prolonged but truncate in the basal centre; apically truncate; 9-10 mature concave lime spirals; weakly calcified and a brittle apical plate that is depressed below the peripheral zone; apical junction at a point or forms a short line; basal pore with an outer opening in the bottom of a pentagonal depression; pore cone-shaped.

Table 7. Measurements of *Lychnothamnus* sp. indet.

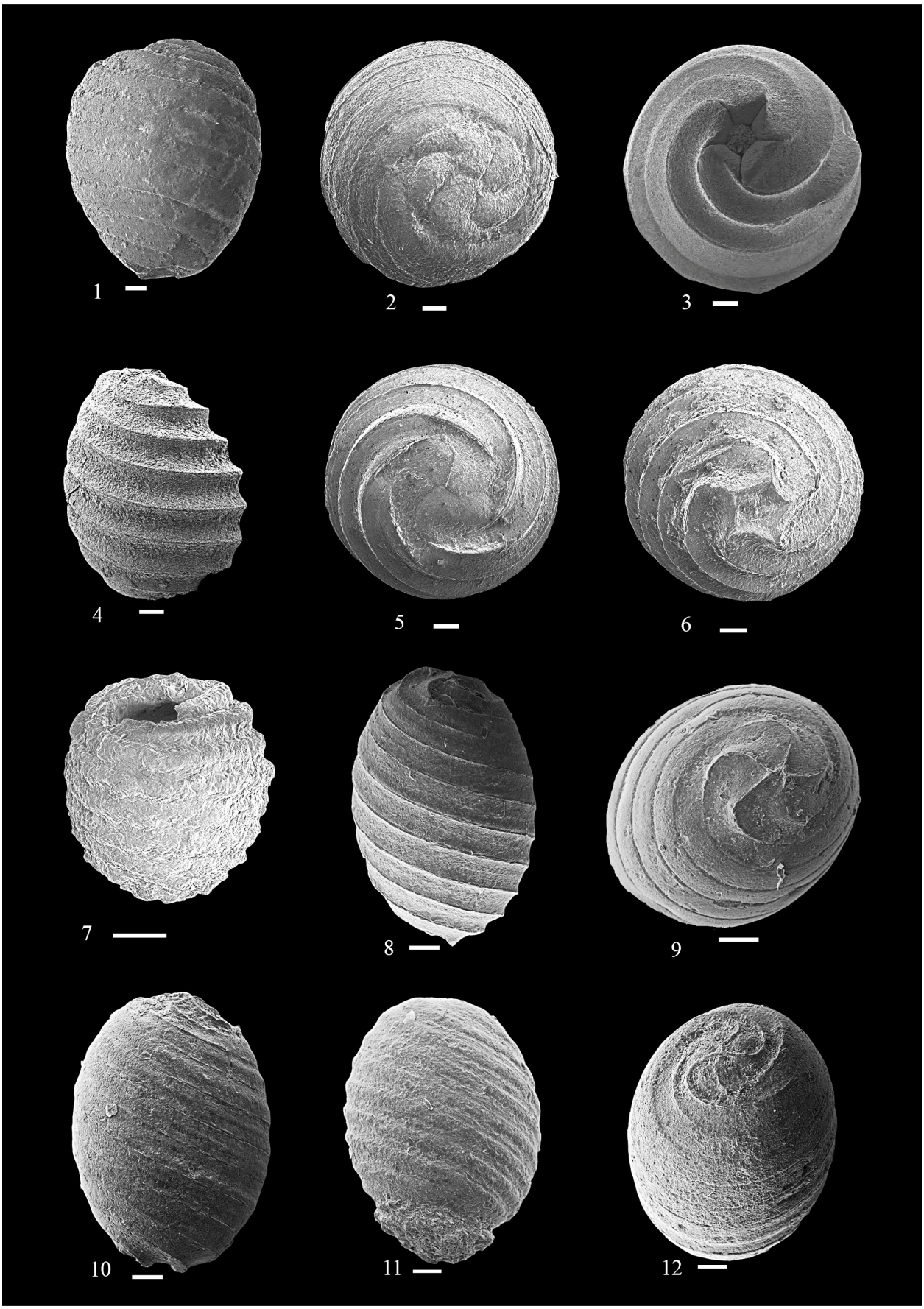
C.No.	LPA (µm)	LED (µm)	AND (µm)	ISI (LPA / LED * 100)	ANI (AND / LPA * 100)	Lsp (µm)	No. of convolutions
BSIP 41932 / UB / NTC / 119	938.7	688.2	520.7	136.3	55	132.4	9

*Remarks***:** The affinities of this gyrogonite with any known species of *Lychnothamnus* cannot be currently ascertained due to insufficient number of gyrogonites. This species is recorded for the first time from the Siwalik Group.

PLATE III →

Plate III: 1-3, *Nitellopsis(Tectochara) merianii:*1, lateral view; 2, apical view; 3, basal view. 4-6, *Lychnothamnus sp*: 4, lateral view, 5. apical view, 6. basal view.7 *Sphaerochara tewarii*, lateral view; 8-9 *Lychnothamnus barbatus*: 8, lateral view; 9, apical view. 10-12*, Lamprothamnium papulosum*: 10, lateral view; 11, lateral view; 12, apical view. Scale Bar = 100 µm.

Plate III



Genus ***Lychnothamnus*** (Ruprecht) v. Leonhardi 1863 emend A. Braun, 1882

Lychnothamnus barbatus (Meyen) v. Leonhardi 1864 (Pl. III, Figs. 8,9)

Referred specimens: BSIP41932/UB/NTC/122-123

Description- The lime shells are medium sized, elongated oval and in shape. Wide and flattened apex without any apical nodule, 8-10 flat to concave convolutions, with moderately prominent double sutures, well developed and a protruding basal funnel is present.

Table 8. Measurements of *Lychnothamnus barbatus*

C.No.	LPA	LED	AND	LPA/ LED* 100 ISI	AND/ LPA* 100 ANI	Lsp	No. of convolutions
BSIP 41932 / UB / NTC / 122	948.4	631.3	500.1	150.2	52.7	113	10

Remarks- L. barbatus is the single extant species of the genus Lychnothamnus, which was earlier reported from some localities of Europe, Asia and Australia and recently it was discovered in North America also. This is a fresh water species, it has been reported from the Ganga plain in India by Bhatia (2006). The range of variation of this species is: LPA 780-1150; LED 610-850; Lsp 110-125.

Genus ***Sphaerochara*** Mädler, 1952

Sphaerochara tewarii Bhatia and Mathur, 1978 (Pl. III, Fig. 7)

Referred specimens: BSIP41933/UB/NTC/124

Description: Gyrogonite small-sized, broadly prolate spheroidal to narrowly oblate spheroidal or ellipsoidal to subovoidal; lime shells apically rounded to subtruncate, and basally rounded or slightly protruding conically; truncated in apical peripheral zone in lateral view; 8-10 flat to convex moderately thick convolutions; apical junction punctiform or forms a short line; basal pore opening pentagonal to subcircular, present at the same level or slightly below the surface of the surrounding spiral cells.

Table 9. Measurements of *Sphaerochara tewarii*

S.No.	LPA (µm)	LED (µm)	AND (µm)	ISI (LPA / LED* 100)	ANI (AND / LPA *100)	Lsp (µm)	No. of convolutions
BSIP 41933 / UB / NTC / 124	344.9	365.1	203	94.4	58.8	57.4	9

Remarks: Identification of *Sphaeochara tewarii* in the present collection is based on a single gyrogonite. The species was first described from the Middle Siwalik (Dhok Pathan Formation) of Himanchal Pradesh by Bhatia and Mathur (1978). The range of variation of this species is: LPA 310-400; LED 330-380; Lsp 55-58.

Bhatia (1999) also described *S. prolifera* from the Middle Siwalik. The Mohand specimens differ from *S. prolifera* in having a rounded apex and their smaller size. *Sphaeochara* (*S*. sp. indet.) has also been reported from the Lower Siwalik Chinji Formation (Bhatia and Mathur 1978). Outside India, at the generic level, *Sphaerochara* is widely known from the Tertiary sequences of Europe and North Africa (e.g. Feist-Castel 1977; Feist et al 1994;Sanjuan and Martín-Closas 2014).. *Sphaerochara* is known from the Quaternary of North Africa (Soulié-Märsche, 1989).

Genus ***Lamprothamnium*** Groves, 1916

Lamprothamnium papulosum (Wallr.) Groves, 1924 (Pl. III, Figs. 10,11,12)

Referred specimens: BSIP41934/UB/NTC/125-127

Description- The gyrogonites are medium to small in size; subprolate to prolate spheroidal; 10-12 concave to flat convolutions; no ornamentation present ; characteristic thin apical portion is rarely preserved ; basal pore wide and pentagonal in shape.

Table No. 10. Measurements of *Lamprothamnium papulosum*

C.No.	LPA (µm)	LED (µm)	AND (µm)	ISI (LPA/ LED* 100)	ANI (AND/ LPA* 100)	Lsp (µm)	No. of convolutions
BSIP 41934 / UB / NTC / 125	847.4	732.1	393.5	115.7	46.4	90.3	10
BSIP 41932 / UB / NTC / 126	917.6	674.1	471	136.1	51.3	95.2	10

Remarks-Bhatia (1999) reported *Lamprothamnium papulosum* and *Lamprothamnium succintum* from Pinjor beds of Upper Siwalik for the very first time, and it was suggested that the species must have flourished in an oligo to mesohaline environment, although the genus is euryhaline and grows vigorously in brackish water with its growth increased during phases of lower salinity (Soulie-Marsche, 1991).Later it was reported by Sharma et al. (2015) from Dhok Pathan beds exposed near Polian Prohita, extending its range from Middle Siwalik to Upper Siwalik. The range of variation of this species is: LPA 790-950; LED 630-750; Lsp 85-95.

Family Feistiellaceae

Genus ***Nitellopsis*** Hy, 1889

Subgenus ***Tectochara*** L. & N. Grambast

Nitellopsis (*Tectochara*) *megarensis* Soulié-Märsche, 1979 (Pl.II, Figs. 7-9)

Referred specimens: BSIP41935/UB/NTC/128-130

Description: Gyrogonites broadly rounded to ovoidal; heavy calcification in some lime shells; 6-8 convolutions, flat to convex; apical pole slightly protruding with distinct apical nodes; basal pole truncate to rounded; lime shells having truncate basal pole have a broad basal funnel that surrounds the basal opening; unusual “stomata-shaped” protrusions present at the sutures of lime spirals.

Table 11. Measurements of *Nitellopsis (Tectochara) megarensis*

C.No.	LPA (µm)	LED (µm)	AND (µm)	ISI LPA /LED * 100	ANI AND / LPA * 100	Lsp (µm)	No. of convo-lutions
BSIP 41935 / UB / NTC / 128	1022.8	925	537.5	110.5	52.5	162.5	7

Remarks: The morphological characters of over 25 gyrogonites in the collection are generally similar to those of other species of *Nitellopsis* (*Tectochara),* but the Mohand specimens closely resemble *T. meriani diluviana* reported by Tewari and Sharma (1972) from the Upper Siwalik sediments exposed near Chandigarh. The known variation of this species is as follows: LPA 1000-1050; LED 850-950; Lsp 155-165.The reason for the presence of stomata-shaped protrusions is unclear, but this phenomenon is possibly related to a differences in calcification pattern and process resulting from external disturbances (Bhatia et al., 1998). This species is also known from the Hirpur Formation of the Karewa Group of Kashmir (Bhatia *et al*., 1998).

Nitellopsis (Tectochara) huangii (Lu, 1945) Grambast & Soulié-Märsche, 1972
(Pl. II, Figs.10-12)

Referred specimens: BSIP41935/UB/NTC/131-133

Description: Gyrogonites range in shape from prolate spheroidal to sub prolate, subovoidal or ellipsoidal, predominantly subovoidal; apically rounded to subtruncate, basally protruding and generally conically prolonged; lime shells strongly calcified, and the lime spirals are mature and are flat to strongly convex; lime spirals thick in the apical periphery forming a distinct apical rossete with inflated spiral tips, joining each other at a zigzagged line; basal pore characteristically protruding and wide, with its shape varying from pentagonal to subcircular.

Table 12. Measurements of *Nitellopsis (Tectochara) huangi*

C.No.	LPA (µm)	LED (µm)	AND (µm)	ISI (LPA / LED* 100)	ANI (AND / LPA * 100)	Lsp (µm)	No. of convo-lutions
BSIP 41935 / UB / NTC / 131	800.1	626	417	127.8	92	52	11

Remarks: Ten gyrogonites in the collection are referable to this subspecies. It was initially described from the Lower Siwaliks (Bhatia and Mathur 1978) but was later also reported from the Pliocene Tatrot Formation of the Upper Siwaliks (Bhatia, 1999). The known variation of this species is as follows: LPA 800-950; LED 600-750.The present find is the first such record from the Middle Siwaliks. Its characteristic, protruding basal pore, which is wide and pentagonal to subcircular in shape, distinguishes this subspecies from other subspecies of *Nitellopsis merianii*. Lu 1945, and Horn of Rantziene 1959 originally described this subspecies from the Kuchar Group of Sinkiang Province, China. It was widely distributed in Europe and Asia (Wang, 1961,1965; Castel, 1967). -

Nitellopsis (Tectochara) meriani
(Al. Braun & Unger, 1850) Grambast & Soulié-Märsche, 1972
(Pl. III, Figs.1-3)

Referred specimens: BSIP41935/UB/NTC/134-136

Description: Lime shells range in shape from prolate spheroidal to sub prolate, subovoidal or ellipsoidal, but predominantly subovoidal; apically rounded to subtruncate; protruding at the base, and generally conically prolonged; lime shells strongly calcified; spirals flat to strongly convex; lime spirals thick in the apical periphery, forming a distinct apical rosette with inflated spiral tips, joining each other at a zigzagged line; basal pore situated in the bottom of a large, regularly pentagonal depression, with a narrow pore opening.

Table 13. Measurements of *Nitellopsis (Tectochara) meriani*

C.No.	LPA (µm)	LED (µm)	AND (µm)	ISI (LPA / LED * 100)	ANI (AND / LPA * 100)	Lsp (µm)	No. of convoluti-ons
BSIP 41935 / UB / NTC / 134-136	1122.6	922.8	592	121.5	52.7	136	10

Remarks: This rare species in the present collection (7 gyrogonites) is widely distributed in the Oligocene to Pliocene horizons of Europe including southern Germany, Austria, Switzerland and France and in the Asian Miocene basins of Northern Thailand (Soulie Marsche *et al*., 1997). Originally, this species was described from Oligocene/ Miocene of Switzerland (Horn af Rantzien, 1959). The size and morphological variation of this species are as follows: LPA 1190-1330; LED 900-1190; number of convolutions 8-10; widths between the convolutions ranges from 130 to 180.

In India, *Nitellopsis meriani* was first recorded from the Lower and Middle Siwalik (Chinji and Dhok Pathan Formations) by Bhatia and Mathur (1978). Subsequently, Bhatia (1999) extended its range to the Upper Siwalik Tatrot Formation (Pliocene).

ASSOCIATED BIOTA

A few freshwater molluscs (gastropods) and ostracods were recovered together with the charophytes. Gastropods include a planorbid (*Gyraulus* sp.), characterised by a planispiral shell with 3-4 whorls separated by deep sutures. Similar specimens are known from the Miocene and Pliocene of the Churia Group of Nepal (Gurung *et al*., 1997). Another taxon, characterised by a turreted spire and up to 7 whorls divided by shallow sutures, is referable to a cerithioidean *Plotia* cf. *P. scabra* described by Bhandari *et al*. (2014) from the Mohand area. Ostracods are represented by carapaces of a single species referable to *Stenocypris* sp. (family Candonidae). Diagnostic characters of these carapaces include rounded anterior and the posterior margins; left valve larger than right valve, with complete overlap and the greatest height more or less in the middle. Similar ostracods have

been reported from the Upper and Middle Siwalik deposits (Sharma et al. 2015).

DISCUSSION AND CONCLUSIONS

As presently known, the Mohand Middle Siwalik fauna (~9-5 Ma) comprises small mammals (Rodentia), fishes and invertebrates (gastropods and ostracods), whereas floral remains include angiospermous pollen grains, pteridophytic spores along with charophytes. The charophyte assemblage (~9 Ma) described in this paper adds significantly to the fossil biota from this reasonably well dated section (Tiwari and Bhandari, 2014).

Based on the recovered microfossil assemblage, the general paleoenvironmental scenario of the Mohand Rao region can be visualised as a shallow, warm, low energy, semi-permanent to permanent lake or pond. *C. globularis*, which occurs abundantly in the present collection, is known for its relatively wide ecological amplitude and is frequently observed in different kinds of water bodies with their optimum occurrence in meso-eutrophic and eutrophic waters, on the shallow, organic and organic-mineral habitats (Pelechaty et al. 2004). Today, *C. globularis* is found in waters up to a depth of 4m. *Chara aspera* occurs abundantly in calcareous waters in the present-day. Their abundance is also attributed to their capability of producing a large number of oospores, which remain fertile for a longer period of time (Auderset Joye & Boissezon, 2015). The ostracod *Stenocypris* is usually found in warm, shallow water ponds and lakes (Bhatia,1996), thereby corroborating the shallow and warm environment deduced from charophytes. However, this paleoenvironmental setting is somewhat inconsistent with the occurrence of of *Nitellopsis* (*Tectochara*) *merianii* in the present assemblage, since the single living representative of this genus (*N. obtusa*) thrives in permanent, cold, alkaline waters at a depth range of 4-11 m (Krause 1985; Soulié-Märsche *et al*., 2002). The presence of *N. merianii* in the Mohand assemblage may possibly be due to migratory birds which feed on this gyrogonite, a mode of dispersal similar to waterfowl from Laguna de Gallocanta, whose stomach content was found to have 95% of charophyte material (Guiral Pellegrin, 1981).

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