www.gondwanags.org.in

Original Article

ISSN : 2455-1953

JGSR
Journal of Geosciences Research
Vol. 7, No.2, July, 2022, pp. 172-178

Late Pliocene-Early Pleistocene Charophyte Gyrogonites from Mudstone Horizon Underlying Volcanic Ash Beds of Northwest Himalaya: Palaeoecological and Palaeoenvironmental Implications

Som Nath Kundal

Department of Geology, University of Jammu, Jammu-180006 (JK), India
(Email: snkundal123@yahoo.com)

Abstract

In this paper, a good number of charophyte specimens and angiospermae seeds have been documented from the mudstone horizon underlying the geochronologically dated volcanic ash beds exposed about 0.375 km northwest of Badakhetar village in Samba district of the Jammu region, northwest Himalaya. By using the morphological characteristics (equatorial axis, distance from apical pore to equatorial axis, isopolarity index, anisopolarity index, width of convolution, angle between convolution and equatorial axis, number of convolutions, vertical and oblique line spiral, size, shape, basal pore and apex morphology) of charophytes, these specimens have been identified and tentatively referred as *Chara rantzieni, Charaglobularis globularis, Chara globularis aspera (Characontraria*), *Hornichara maslovi, Lamprothamnium papulosum, Lychnothamnus breviovatus and Boraginocarpus lakhanpalii* (Angiospermae seed). The reported species of charophytes are used here in the present study for Palaeoecological and Palaeoenvironmental studies.

Keywords: Charophyte Gyrogonites, Mudstone Horizon, Northwest Himalaya, Palaeoecology, Palaeoenvironment

Introduction

Charophytes are aquatic (wetland, freshwater, brakish water) plants and have an intermediate position between the green algae and the terrestrial plants (Soulie-marsche, 1999). They form an important part of the micro biota of large and small fresh water habitats. Today there are about 84 genera and 678 species of charophytes which have been identified and recognized (Guiry and Guiry, 2020) including both in extinct and extant state. The oldest known record of charophytes is from Late Silurian. Various authors (Groves, 1924; Corillion, 1957; Pal *et al.*, 1962; Wood, 1965; Blindow, 1992; Tambareau *et al.,* 1991; Liu, 1992; Hussain *et al.*, 1996; Ling *et al.,* 2000; Langangen and Leghari, 2001; Subramanian, 2002; Blaženčić *et al.*, 2006; Penning *et al.*, 2008; Ahmadi *et al.*, 2012; Henriksen and Hilmo, 2015; Schneider *et al.*, 2016; Borges and Necchi, 2017; Kumar *et al.*, 2018; Girbau and Soulié-Märsche, 2020; Zalat *et al.*, 2020; Mjelde *et al.,* 2021; Saber *et al.*, 2021; Brzozowski *et al.*, 2022) published their work on charophytes in different part of world from time to time on taxonomy, morphology, composition, evolution, genomic DNA studies, phylogeny, palaeoecology, palaeoenviron-ment, habitats, age and distribution.

In Siwalik of India, the work carried out on fossil charophytes by a few authors (Sahni, 1936; Bhatia and Mathur, 1970, 1978; Tewari and Sharma, 1972; Lakhanpal *et al.*, 1974; Tewari and Natarajan, 1978; Kumar *et al.*, 1979; Bhatia, 1996; Bhatia *et al.*, 1998; Bhatia, 2003). The first record of charophytes was from Tatrot and Pinjor formations of Siwalik Group near the city Chindigarh, India (Bhatia and Mathur, 1970). Bhatia (1999) revised the whole charophyte flora of the Siwalik Group.

In Siwalik of Jammu region, a good work on vertebrate and ichnofossils carried out (Verma *et al.*, 2002; Prasad *et al.*, 2005; Kundal *et al.*, 2021, 2022), but not much work on fossil charophytes /microfossils has been carried out except a few workers (Suneja and Singh, 1979a, 1979b; Suneja *et al.*, 1980; Bhatia *et al.*, 2001; Bhandari and Kundal, 2008; Kundal, 2015). The aim of the present work is to document the charophytes flora from the mudstone horizons underlying volcanic ash beds (Fig. 1) and their Palaeoecologic and palaeoenvironmental significance.

Stratigraphy of the Study Area

Siwalik is the southernmost part of the Himalaya and divided into three subgroups (Lower Siwalik Subgroup, Middle Siwalik Subgroup, Upper Siwalik Subgroup) and seven formations (Kamlial, Chinji, Nagri, Dhok Pathan,Tatrot, Pinjor and Boulder Conglomerate) (Pilgrim, 1934). All the seven formations of the Siwalik Group are well exposed in the Jammu region of Jammu and Kashmir. A few authors (Agarwal *et al.*, 1993; Gupta, 2000; Elyas *et al.*, 2017) gave local classification of the Jammu Siwalik based on lithologic, vertebrate fauna, satellite

(Received : 14 December 2021 ; Revised Form Accepted : 25 April 2022)
https://doi.org/10.56153/g19088-021-0082-12

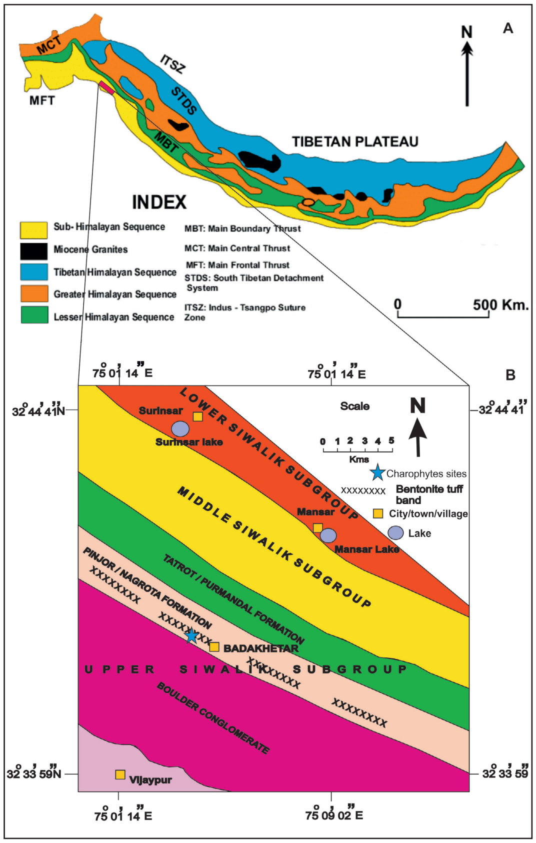

Fig.1. Tectonic divisions of Himalaya (A). Locality map of study area (B) (Gupta and Verma, 1988)

imaginary and magnetostratigraphy. A comparative stratigraphical classification of the Siwalik of Jammu is given in table 1. A well preserved volcanic ash layer is occurring in the Pinjor/Nagrota/ Uttarbaini Formation which has been geochronologically dated. Ranga Rao *et al.* (1988) correlated this volcanic ash layer with the Gauss-Matuyama boundary. In the present work, the documentation of charophytes carried out from the mudstone horizon immediately underlying the geochrologically dated volcanic ash layer in the Pinjor / Nagrota / Uttarbaini Formation of the Upper Siwalik Subgroup of Jammu.

Methodology

Samples of mudstone have been collected from the charophytes / microfossils bearing mudstone horizon underlying the geochronologically dated volcanic ash beds occurring 0.375 km northwest of Badakhetar village. The collected samples transported to the maceration laboratory, Department of Geology, University of Jammu for maceration. In the laboratory, the collected samples first immersed in water for four to five hours. This leads to disintegration of the samples. Disintegrated samples then macerated using different sets of sieves (40ASTM, 60ASTM, 80 ASTM, 100 ASTM). The residue so obtained dried in the sunlight. The picking and identification of charophytes carried out under stereo-zoom binocular microscope. The photomicrography was done with the help of attached camera with the stereo-zoom trinocular microscope. The recovered specimens of charophytes preserved in the Vertebrate palaeontology laboratory using VPL/JU/C/ numbers.

Systematic Palaeontology

Division: Charophyta; Order: Charales
Family: Characeae; Subfamily: Charoidae;
Genus: *Chara* Linne
***Chara rantzieni* Tewari and Sharma**
(Fig.2 d-g)

Grambastichara rantzieni Tewari and Sharma, Bull. Ind. Geol. Assoc. 5:7-9, pl. 1, fig 3a-c, text fig.2, fig. 3a-c (1972)

Chara rantzieni Tewari and Sharma, Bhatia and Mathur, Geophytology 8(1): 93-94, pl. 3, fig. 1a-c, 2a-c (et syn.) (1978).

Referred Material: VPL/JU/C/01, more than 100 gyrogonites

Locality: In a stream cutting, 0.375 km northwest of Badakhetar village, Samba district, Jammu and Kashmir.

Stratigraphic Position: Mudstone horizon immediately underlying Upper Siwalik bentonitized band of the Nagrota / Uttarbaini Formation

Table 1: Lithostratigraphic classifications of the Northwest Siwalik sequence

GROUP	Siwalik Subgroup	Ranga Rao *et al.* (1988) (Jammu Siwalik)	Agarwal *et al.* (1993) (Jammu Siwalik)	Gupta and verma (1988); Gupta (2000) (Jammu Siwalik)		Classica subdivisions Pilgrim, 1934	Proposed Formations Eliyas *et al.* (2017) In Indian part of NW Siwalik	Age
		Boulder Conglomerate		Dughor Formation		Boulder Conglomerate	Kalar	Lower Pleistocene
	Upper Siwalik subgroup	Nagrota Formation	Nagrota Member A Nagrota Member B Nagrota Member C	Uttarbaini Formation	Marikhui Member	Pinjor Formation	Pinjor Formation	Lower Pleistocene
		Purmandal Sandstone			Labli Member	Tatrot Formation	Saketi Formation	Upper Pliocene
	Middle Siwalik subgroup			Mohargarh Formation (= Purmandal Sandstone of Ranga Rao *et al.* 1988)		Dhok Pathan Formation	Mohargarh Formation	Middle Pliocene
				Dewal Formation		Nagri Formation	Dewal Formation	Lower Pliocene
	Lower Siwalik Subgroup			Mansar Formation	Ramnagar member	Chinji Formation	Nahan Formation	Upper Miocene
					Dodenal Member	Kamlial Formation	Dodenal Member	Middle Miocene

Descrption: Gyrogonites prolate-spheroidal in outline and medium in size; 8-10 Convolutions; convolutions non- segmented and dextrally coiled; intercellular ridges are not sharp; gyrogonites show well-developed apical rosette structure; spiral cells are convex or flat; basal pore opening is pentagonal in outline; apical area broadly rounded; width decreases gradually towards the base; slightly larger than wide; apically cells form a brevicharoid structure.

Remarks: In having a well developed rosette apically the present gyrogonites differ from those of *Chara globularis globularis* and are more closer to those of *Chara rantzieni* (Tewari and Sharma) Bhatia and Mathur (1978). *Chara rantzieni* ranges from Pliocene to Recent and has been reported earlier from the Tatrot Formation (Tewari and Sharma, 1972; Bhatia and Mathur, 1978) from the Pliocene of Greece (Soulié-Märsche, 1989) and Quaternary marl of Indo- Gangetic plain (Bhatia and Singh, 1989).

***Chara globularis globularis* Thuillier**
(Fig. 2 h-k)

Chara globularis Thuillier (non vidi)

Charites indica Tewari and Sharma 1972, *Bull. Ind. Geol. Assoc*. 5: 6-7, pl. 1, fig. 2a-c; text fig. 2a-c (1972)

Chara rantzieni sivalensis (Bhatia and Mathur 1978) *Geophytology* 8(1):95, pl.3. fig. 3a-c (1978)

Chara surajpurica Tewari and Sharma 1972, Bhatia and Mathur 1978 *Geophytology* 8(1):95, pl.3. fig. 5a- c

Chara globularis cf. *globularis* Thuillier, Soulié-Märsche, Tilleuls Millau 137: pl. 24, figs 1-8 (1989)

Referred Material: VPL/JU/C/02, more than 250 gyrogonites

Locality: In a stream cutting, 0.375 km northwest of Badakhetar village, Samba district, Jammu and Kashmir.

Stratigraphic Position: Mudstone horizon immediately underlying the Upper Siwalik bentonitized band of the Nagrota/Uttarbaini Formation.

Description: The shape of the gyrogonites is oblate-spheroidal to prolate-spherical, spiral cells, convex or flat, 10-11 convolutions, convolution and equatorial axis angle is 15^0; width of the convolution very small, lime spirals are obliquely placed and dextrally coiled; the gyrogonites show charoid apical rosette; basal pore opening is pentagonal in shape; the length is little more than its width; apical region broadly rounded; width of the gyrogonites decreases gradually towards the base.

Remarks: *Chara globularis globularis* Thuillier is an extant species (Soulié-Märsche, 1989) and has also been reported as a fossil from the Dhok Pathan, Tatrot and Pinjor Formations of the Siwalik Group exposed near Chandigarh and Saketi (H.P.). In the present collection, there is a large number of gyrogonites morphologically similar to those of *Chara globularis globularis* Thuillier. This species was reported for the first time from India by Bhatia (1999). The presence of this species in the Nagrota Formation of the Upper Siwalik of Jammu region is indicative of lacustrine environment.

***Chara globularis aspera* (Deth. Ex Willd.) Wood**
(Fig. 2 l-o)

Chara contraria Bhatia and Mathur, 1978

Referred Material: VPL/JU/C/03, more than 300 gyrogonites

Locality: 0.375 km northwest of Badakhetar village, Samba district, Jammu and Kasmir.

Stratigraphic Position: Mudstone horizon immediately underlying the Upper Siwalik bentonitized band of Nagrota/Uttarbaini Formation.

Description: Gyrogonites perprolate in shape, spiral cells vary in number from 10-12, flat or convex, sometimes concave, intercellular ridges are not sharp, length of the gyrogonites is more than twice their width, apically broadly rounded and the angle between the convolution and the equatorial axis is $<20^0$. Spiral cells join at slightly elevated point in a rosette (brevicharoid), the basal pore is pentagonal in shape.

Remarks: Morphologically, the present gyrogonites are closely comparable to those of Chara globularis aspera described from the Tatrot and Pinjor Formation (Bhatia, 1999). Soulié-Märsche (1991) considered this species as a lacustrine biomarker in the Quaternary of Africa. This species has also been documented from the Quaternary marls of Indo-Gangetic plain (Bhatia and Singh, 1989).

Genus *Hornichara* Maslov, 1963
***Hornichara maslovi* Bhatia and Mathur, 1978**
(Fig. 3 a-d)

Referred Material: VPL/JU/C/04, more than 700 gyrogonites

Locality: 0.5 km North of Uttarbaini village across the river Devak, Samba district, Jammu and Kashmir.

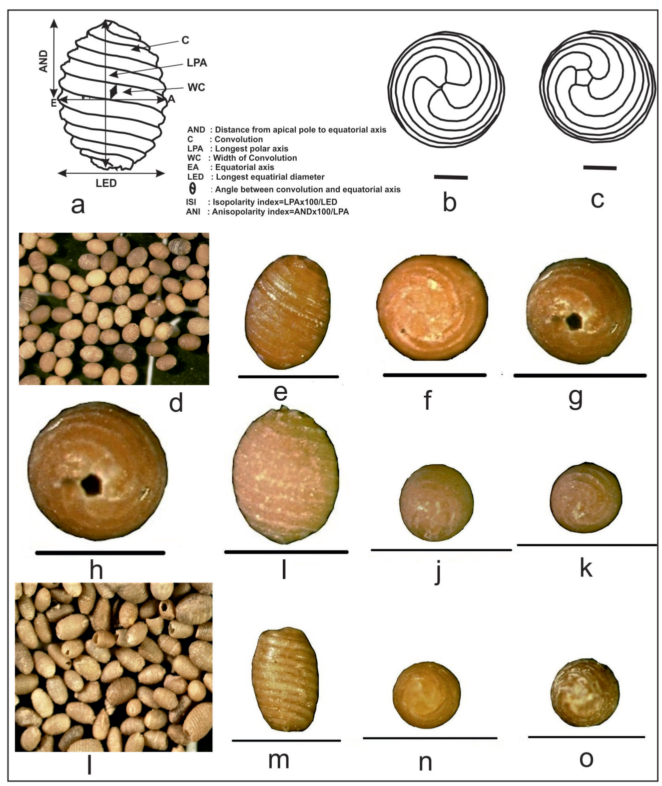

Fig.2. line drawing showing morphological characters of charophytes (a. lateral view, b. apical view, c. basal view). *Chara rantzieni*sp. (d a. bunch, e. lateral view, f. apical view, g. basal view), *Chara globularis globularis* (h. basal view, i. lateral view, j. apical view, h. basal view), *Chara globularis aspera* (l. bunch, m. lateral view, apical view, basal view). Scale bars equal 1mm.

Stratigraphic Position: Mudstone horizon immediately underlying the Upper Siwalik bentonitized band of Nagrota/ Uttarbaini Formation.

Descrption: Gryogonites small, predominantly subprolate, occasionally prolate spheroidal and ellipsoidal; apically broadly rounded, basally conically produced; 7-9 moderately wide obliquely and dextrally coiled, concave convolutions; intercellular ridges sharp, width of the spiral cells slightly narrower in the apical periphery than in the apical center; apical cells joined at a point, basal cells produced into a nozzle; basal pore narrow to moderately wide, pentagonal, basal plug thinner than wide; apical structure charoid, un-segmented coiled, spiral cell 100µm thick in the equatorial region; angle between the convolution and the equatorial axis is 15^{o}.

Remarks: In a preliminary note, Bhatia and Mathur (1970) referred gyrogonites from the Tatrot Formation questionably to *Hornichara maslovi*. Following this, Bhatia and Mathur (1978) described additional gyrogonites from the Pinjor Formation and assigned them to a new species *Hornichara maslovi* Bhatia and Mathur, 1978. Apparently, this species is restricted to the Tatrot and Pinjor Formation (Bhatia and Mathur, 1978). The gyrogonites from the Upper Siwalik beds of Uttarbaini compare well with those of *H. maslovi* Bhatia and Mathur, 1978 in all respects and hence are referred to this taxon.

Genus: *Lamprothamnium* Groves
***Lamprothamnium papulosum* (Wallr) Groves**
(Fig. 3 e-h)

Lamprothamnium papulosum Groves, Jour. Bot. 54:337 (1916)

Lamprothamnium papulousm (Wallr.) Groves, Soulié-Märsche, Cent. Nat. Rech. Sci Paris: 8081, pl. 15, figs 1-7 (1982); Soulié-Märsche, TilleukMillau 150: pl. 32 figs 1-10 (1989)

Referred material: JU/VPL/C/05, 200 gyrogonites

Locality: In a stream cutting, 0.375 km northwest of Badakhetar village, Samba district, Jammu and Kashmir.

Stratigraphic Position: Mudstone horizon, immediately underlying the Upper Siwalik bentonitized band in the Nagrota / Uttarbaini Formation.

Description: Gyrogonites are suboblate - spheroidal in outline; apically broadly rounded and truncated, basally conically produced or tapering; intercellular ridges sharp, width of the spiral cells greater in the equatorial region than at the apex; 9-10 concave convolutions, the spiral cells join at a point apically; basal pore pentagonal in shape and is at the same level as the surrounding spiral cell.

Remarks: Similar gyrogonites recovered from a locality near Nadah village, Chandigarh, have been referred to *Lamprothamnium populosum* (Wallr) Groves (Bhatia, 1999). The present report is second such find from the Siwalik Group.

Genus: *Lynhnothamnus* (Rupr.) Leonhardi sensu Soulié-Märsche
***Lychnothamnus breviovatus* Lu and Luo, 1990**
(Fig.3 i-o)

Referred Material: VPL/JU/C/06, more than 25 gyrogonites

Locality: 0.5 km north of Uttatbaini village across the river Devak, Samba district, Jammu and Kashmir.

Stratigraphic Position: Mudstone horizon immediately underlying the Upper Siwalik bentonitized band of the Nagrota / Uttarbaini Formation.

Description: Gyrogonites are suboblate to oblate-spheroidal, slightly longer than wide; number of convolutions varies from 9 to 10; the spiral cells are obliquely and dextrally coiled, non segmented in nature; intercellular ridges are flat and smooth; gyrogonites show brevicharoid structure; the angle between convolutions and equatorial axis is 10^{o}-12^{o}; basal pore is pentagonal in shape.

Remarks: Bhatia (1999) recorded Genus *Lychnothamnus* for the first time from the Siwalik rocks of India and *L. breviovatus*is supposed to have a long geological range extending from DhokPathan Formation to Pinjor Formation. *L. breviovatus* was first described from the Late Oligocene and Neogene deposits of Tarim Basin, Xinjiang, China (Lu and Luo, 1990). *Lychnothamnus barbatus* was reported from the Plio-Pleistocene deposits of the Karewa Group and from the present day lakes of Kashmir (Bhatia *et al.,* 1998).

Phylum: Angiospermae; Subphylum: Dicotyledones
Order: Boraginales; Family Boraginaceae
Genus: *Boraginocarpus* Mathur, 1974
***Boraginocarpus lakhanpalii* Mathur, 1974**
(Fig. 3 m-o)

Referred Material: VPL/JU/A/01, more than 60 specimens

Locality: 0.375 km northwest of Badakhetar village, Samba district, Jammu and Kashmir.

Stratigraphic Position: Mudstone horizon immediately underlying Upper Siwalik bentonitized band of the Nagrota / Uttarbaini Formation.

Description: The shape of the specimens under study is conical or rounded triangle with one broad end and a tapering end. The surface is ornamented with tubercle-like structures.

Remarks: Mathur (1974) reported for the first time fossil seeds of the family Boraginaceae from the Tatrot Formation (Quranwala Zone, *sensu* Sahani and Khan, 1959), about 11 m from the Tatrot-Pinjore boundary, 3.5 km northeast of Saketi, near Chandigarh. Similar specimens have been documented by Bhatia *et al*., (2001) from the mudstone immediately underlying the Upper Siwalik bentonite band. The specimens described here come from the same stratigraphic level as that of Bhatia *et al.* (2001).

Palaeoecological and Palaeoenvironmental Implications

A considerable amount of information is available on the ecology of extant charophytes (Wood, 1965). In contrast, little has been published on the palaeoecology of fossil forms with the exception of a few recent studies (Tambareau *et al*., 1991; Soulié-Märsche, 1993; Lucas and Kietzke, 1994). The ecology of extant and fossil forms is similar, so reference is made to extant ecology while interpreting the ecology of recovered fossil taxa.

Charophytes form dense submerged vegetation in various kinds of continental waters. Their calcified reproductive organs (gyrogonites) represent autochthonous microfossils. Soulie-Marsche (1993) demonstrated that depending upon the species; charophytes can be used to identify deep and cold freshwater lakes,

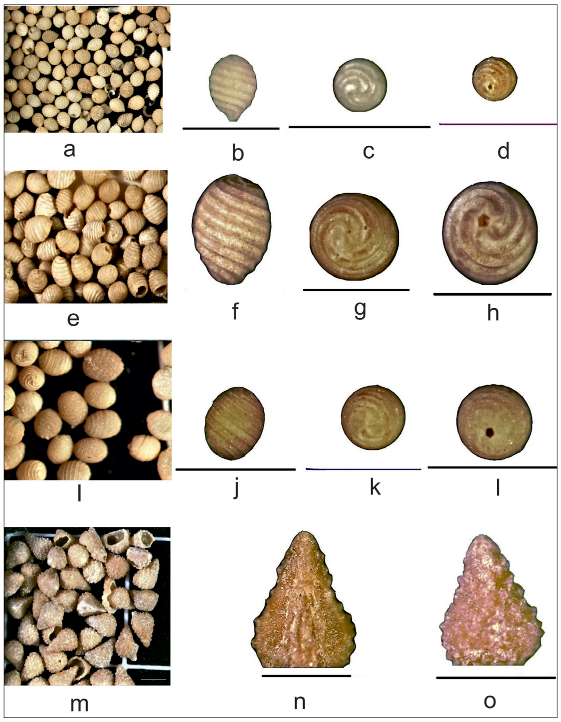

Fig.3. *Hornichara maslovi* (a. bunch, b. lateral view, c. apical view, d. basal view), *Lamprothamnium papulosum*(e. a bunch, f. lateral view, g. apical view, h. basal view), *Lychnothamnus brebiovatus*(i. a bunch, j. lateral view, k. apical view, l. basal view), *Boraginocarpus lakanpalli* (m. a bunch, n. dorsal view, ventral view). Scale bars equal 1mm.

shallow freshwater lakes or marginal zones of deep lakes-tuffaceous deposits originating in springs, temporary ponds with either fresh or brakish water, saline inland waters or tropical lakes. In situ presence of charophyte flora has been shown to indicate supratidal-environment or emerged land (Soulié-Märsche, 1994). Charophytes cannot grow in acid or neutral environments and are not found in non-calcareous sediments. Generally they occur in alkaline water bodies, such as lakes and ponds with pH varying from 7.5 to 8.0. They are superficially fixed on a substratum which may be mud, sand or silt-covered peat and sand (Moore, 1986). The climate, hardness and salinity of water are the most obvious factors affecting of charophytes distribution (Corillion, 1975).The great majority of extant calcified species producing calcified and thus fossilizable oogonia are found in temperatures of inter tropical zones and the fossil record shows the same general distribution (Soulié-Märsche, 1993). In the extant forms, 15 to 200 mg/litre of calcium carbonate ($CaCo_3$) are necessary for the calciphilous species (Corillion, 1975). Another aspect of charophyte ecology is tolerance of salinity. Some species are entirely lacustrine and others are restricted to polyhaline biotypes, but most species support wide ranges of salinity (up to 70ppt, Burne *et al.*, 1980). Submersion duration is a key factor for brackish water habitats because it governs the dynamics of salinity fluctuations. Time and duration of flooding as inferred from biomarkers provide information about lake level and rainfall patterns. A distinction is to be made between ephemeral, temporary and seasonal habitats (Soulié-Märsche, 1991) “Ephemeral” refers to water bodies that last for a very short period. “Temporary” applies to transient events or actions lasting for a limited time span, the duration of which is not precisely defined. “Seasonal” aquatic habitats are flooded at regular intervals corresponding to a given rainy period. They hold water at least for one season every year before drying out. This type is most suitable for the establishment of brackish water charophytes, which are able to provide abundant fossil remains. In a number of freshwater environments, the sediments are largely composed of charophyte remains. Therefore, the presence of charophytes is taken as evidence for alkaline water bodies with little current action.

Majority of the charophytes recovered from the mudstone horizon underlying ash beds have living representatives or closely related forms in the living flora. By making use of the Huttonian principle "Present is the Key to the Past" a reasonably acceptable palaeoecological reconstruction of the area can be made. Since the physical, chemical, and biological factors that control ecological distribution of a particular taxon might have changed over time, it would be prudent to use all the members of an assemblage or different fossil assemblages so that the palaeoecological interpretations based on one taxon can be tested with that of others. The fossil evidence for the palaeoecological inferences is derived from charophytes, ostracodes and gastropods. The present collection of charaphyte flora is represented as *Hornichara maslovi*, *Chara contraria*, *Chara rantzieni*, *Chara globularis globularis, Lychnothamnous breviovatus, Lamprothamnium populosum*, cf. *Lamprothamnium.* Besides one taxaon of angiospermae seed *Boraginocarpus lakhanpalii,* is also reported. All the species of charophytes of present collection indicate freshwater, shallow lacustrine / pond environment except the species *Lamprothamnium populosum* and cf. *Lamprothamnium* which indicate saline conditions. *Lamprothamnium* is generally found in shallow waters up to a depth of 1-1.5m. *L. papulosum* and cf. *Lamprothamnium* are active and fructify in between 20-40% of salinity. Short period of low salinity down to 10% for germination is also tolerated (Dubois, 1968). This genus occurs neither in permanent freshwater nor in permanently high saline environments. This characteristic makes it particularly valuable as a marker for seasonal rainfall. But its occurrence in the freshwater fluvial / lacustrine sediments poses ecological questions. *L. barbatus* has been reported from the present day lakes of Kashmir (Pal *et al.*, 1962). This is an extant species still living in the Dal Lake with its more than 2 m.y. older ancestors. Soulié-Märsche (1989) has demonstrated that abundance of gyrogonites suggests no transport or reworking during deposition. As transport during deposition would result in homogenous distribution, different distribution patterns or frequencies at different levels would indicate lack of reworking. In the present study, it is noticed that the distribution of charophyte taxa is not homogenous at different sites thus giving little credence to reworking.

Conclusions

The charophytes flora reported from the mudstone stone horizon underlying volcanic ash beds/ bentonitized tuff bands indicates an interfluvial - lacustrine depositional environment for the charophytes bearing mudstone horizon. The recovery of charophyte flora immediately underlying geochrologically dated ash beds indicate that age of charophytes is not younger than the volcanic ash beds. The distributions of charophytes are not homogenous suggesting the little credence to reworking.

Authors' Contributions

Som Nath Kundal: Investigation, Conceptualization, Writing-Original Draft, Formal Analysis, Reviewing and Editing.

Conflict of Interest

The author declares no conflicts of interest.

Acknowledgements

The corresponding author is thankful to Science and Engineering Research Board (SERB), New Delhi for financial support under SERB project and Head, Department of Geology for infrastructure/ laboratory facilities.

References

Agarwal, R.P., Nanda, A.C., Prasad, D.N. and Dey, B.K. (1993). Geology and biostratigraphy of the Upper Siwalik of Samba area, Jammu Foothills. Him.Geol., v. 4(2), pp 227–236.

Ahmadi, A., Riahi, H., Sheidai, M. and Raam, J.V. (2012). Some charophytes (Characeae, Charophyta) from central and western of Iran including *Chara kohrangiana* species nova. Cryptogam. Algolog., v. 33(4), pp.359–390.doi:10.7872/crya.

Bhandari, A. and Kundal, S.N. (2008). Ostracodes from the Nagrota Formation, Upper Siwalik Subgroup, Jammu, India. Rev. Español. Micropaleontol., v.40 (1), pp.151.

Bhatia, S.B. and Mathur, A.K. (1970). First record of Charophyta from the Upper Siwalik near Pinjor. Bull. Indian Geolog. Assoc., v. 3, pp.27-28.

Bhatia, S.B. and Mathur, A.K. (1978). The Neogene Charophyte flora of the Siwalik Group, India, and its biostratigraphical significance. Geophytology, v.8, pp.79-97.

Bhatia, S.B. and Singh, N. (1989). Holocene charophytic flora parts of U.P., India: biogeographic implications. First International Symposium Charophytes, Montpellier. Abstract, 5p.

Bhatia, S.B. (1996). The ostracode fauna and the charophyte flora of the Siwalik Group: palaeobiogeographic and palaeoecologic implications. Publ. Cent. Advanc. Study Geol. Panjab Univ., v. 5, pp.99-106.

Bhatia, S.B., Soulié-Märsche, I. and Gemayel, P. (1998). Late Pliocene and Early Pleistocene Charophyte Floras of the Hirpur Formation, Karewa Group, Kashmir, India. Neues Jahrbuchf. Geolog. Paläontolog. – Abhandlung., v.210(2), pp.185-209.

Bhatia, S.B. (1999). Revision of the charophytes flora of the Siwalik group (Neogene -Quaternary) of the Lesser Himalaya, India. Austral. Jour. Bot., v. 47, pp.459-474.

Bhatia, S.B., Bhat, G.M. and Pandita, S.K. (2001). Microfossils from the Nagrota Formation, Upper Siwalik Subgroup, Jammu Hills. Jour. Geol. Soc. India, v.58, pp. 509- 518.

Bhatia, S.B. (2003). Charophytes from the Miocene-Pliocene transition in the Siwalik/Churia group of the Himalayan foreland basin: palaeobiographic and palaeoecologic implications. Acta Micropalaeontolog. Sin., v.20, pp.150-155.

Blaženčić, J., Stevanović, B., Blaženčić, Z. and Stevanović, V. (2006). Red data list of charophytes in the Balkans. Biodiver. Conservat., v.15(11), pp.3445–3457. doi:10.1007/s10531- 005-2008-5.

Blindow, I. (1992). Decline of charophytes during eutrophication - comparison with angiosperms. Freshwat. Biol., v. 28(1), pp. 9–14. doi:10.1111/j.1365-2427.1992.tb00557.x

Borges, F.R. and Necchi, O.Jr. (2017). Taxonomy and phylogeny of *Chara* (Charophyceae, Characeae) from Brazil with emphasis on the midwest and southeast regions. Phytotaxa, v. 302(2), pp.101–12. doi:10.11646/phytotaxa.302.2.1.

Brzozowski, M., Pełechaty, M. and Bogawski, P. (2022). A winner or a loser in climate change? Modelling the past, current, and future potential distributions of a rare charophyte species. Glob. Ecol. Conserv., v. 34, pp.1-19.

Burne, R.V., Bauld, J. and De deckker, P. (1980). Saline lake charophytes and their geological significance. Jour. Sediment. Petrol., v.50, pp.281-293.

Corillion, R. (1957). Les Charophycées de France etd'Europeoccidentale. Trav Lab FacSc Angers, v.11–12, pp.1–259.

Corillion, R. (1975). Flore des charophytes (characees) du Massif Armoricainet des contreesvoisines d-Europe occidentale, in Jouve, ed., Flore et vegetation du Massif Armoricain, Paris, v. 4, pp.1-216.

Dubois, A. (1968). Observations Sur La morphologic et la biologie des formesnainesde *Lamprothamnium papulosum* J. Groves (characees). Naturalia

Eliyas, N., Khan, N., Kumar, D., Singh, P., Prakash, S., Kumar, R. and Singh, R.J. (2017).Siwalik Group of Northwest Sub Himalaya. National workshop on Indian Siwalik Recent advances and future research. Abstr. Vol., pp.181–205.

Girbau, J.S. and Soulié-Märsche, I. (2020). New charophytes assemblage from middle Miocene lacustrine deposits of Moneva (Ebro Basin, Spain). Geobios, v.59. DOI:10.1016/j.geobios.2020.03.001

Groves, J. (1916). On the name *Lamprothamnus Braun*. Jour. Bot., Brit. and Foreig., v.54, pp.336-337.

Groves, J. (1924). Notes on Indian charophyta. Bot. Jour. Linn. Soc., v. 46(310), pp.359–376. doi:10.1111/j.1095-8339.1924.tb00493.x.

Guiry, M. and Guiry, G. (2020). Algae Base. World-wide electronic publication. Galway: National University of Ireland. https://www.algaebase.org.

Gupta, S.S. (2000). Lithostratigraphy and structure of the Siwalik succession and its relationship with the Muree succession around Ramnagar area, Udhampur district. Jammu and Kashmir. Him. Geol., v.21, pp.53–61.

Gupta, S.S. and Verma, B.C. (1988). Stratigraphy and vertebrate fauna of the Siwalik Jammu District Group, Mansar-Uttarbani section,, J & K. Jour. Palaeontol. Soc. India, v.33, pp. 117-124.

Henriksen, S. and Hilmo, O. (2015). The 2015 Norwegian red list for species. Norway: Norwegian Biodiversity Information Centre.

Hussain, M.I, Khoja, T.M. and Guerlesquin, M. (1996). Chemistry, ecology and seasonal succession of charophytes in the Al-Kharj Irrigation Canal, Saudi Arabia. Hydrobiologia, v. 333(2), pp.129–137.

Kumar, A., Suneja, I.S. and Chopra, S.R.K. (1979). First record of Charophytes from Lower Siwalik around Ramnagar. Geophytology, v. 8, pp. 246.

Kumar, S, Stecher, G., Li, M., Knyaz, C. and Tamura, K. (2018). MEGA X: molecular evolutionary genetics analysis across computing platforms. Mol. Biol. Evol., v.35(6), pp.1547–1549. doi:10.1093/molbev/msy096.

Kundal, S.N. (2015). Microfossils based Palaeoecology and Palaeocommunity Structure of Upper Siwalik Deposits of Jammu, J and K, India. Internatl. Res. Jour. Biol. Sci., v.4 (1), pp. 34-40.

Kundal, S.N., Pachnanda, N., Kumar, S., Malik, M.A. and Chowdhary, N. (2021). *Stegolophodon* cf. *S. latidens* (Probscidea, Mammalia) from Mohargarh Formation (Dhok Pathan Formation), Jammu Province, Jammu and Kashmir, India. Jour. Geosci. Res., **v. 6(**2), pp.197-204.

Kundal S.N., Kundal P., Kumar, S., Chowdhary N, Prasad G.V.R. (2022). Late Pliocene–Early Pleistocene ichnofauna from bentonitized tuff band and associated mudstone horizons, Jammu and Kashmir, India, and their palaeoenvironmental implications. Arab. Jour. Geosci., v. 15, pp. 269.

Lakhanpal, R.N., Kapoor, S. and Jain, K.P. (1974). Some Charophytic remains from the Lower Siwalik of Tanakpur, District Nainital.

The Palaeobot., v.23, pp.40-43.
Langangen, A. and Leghari, S.M. (2001). Some charophytes (Charales) from Pakistan. Stud. Bot. Hung., v.32, pp.63–85.
Lu, H. and Luo, Q. (1990). Fossil charophytes from Tarim Basin, Xingiang. Scientific and Technical Documents, Publishing House, Beijing.
Liu, J.Y. (1992). Discovery of fossil Charophytes from the Lower member of the Binai Khola formation, the Churia (Siwalik) group, in Nepal and its significance. Acta Micropalaeontol. Sin., v.9, pp.311-319.
Ling, Y.J, Xie, S.L. and Langangen, A. (2000). Charales of China. Nowa Hedwigia, v.71(1–2), pp.69–94.
Lucas, S. G. and Kietzke, K.K. (1994). Pliocene microfossils from the Monticello Pointmaar, Sierra County, New Mexico. New Mexico Geol., v.16 (3), pp.41-48.
Maslov, V.P. (1963). The discovery of the calcareous crown and the apical structure of the fruit bearing organs of fossil charophytes. Dokl. Akad. Nauk. SSSR, v.149, pp. 954-956. [Paleobotany] [Russian, english translation (American Geological Institute): Proc. Acad. Sci. SSSR, v.149 (1965), pp.196-198.
Mathur, A.K. (1974). A new fossil seed (Boraginaceae) from the Siwalik Group. Bull. Ind. Geol. Assoc., v. 7(1), pp.43-49.
Mjelde, M., Swe, T., Langangen, A. and Ballot, A. (2021). A contribution to the knowledge of charophytes in Myanmar; morphological and genetic identification and ecology notes. Bot. Lett., v. 168 (1), pp.102-109. DOI:10.1080/23818107.2020.1847189
Moore, J.A. 1986. Charophytes of Great Britain and Ireland. Bot. Soc. British Isles, Handbook No. 5,140p.
Prasad, G**.**V.R.**,** Kundal, S.N. and Bhat, G.V.R. (2005). Mandible of Golunda (Rodentia, Mammalia) from the Upper Siwalik Subgroup of Jammu, India. Annal. Paléontolog., v. 91(2), pp.181-196.
Pal, B., Kundu, B., Sunderlingam, V. and Venkataraman, G. (1962). Charophyta. New Delhi: ICAR Monograph on Algae.
Penning, W.E, Mjelde, M., Dudley, B., Hellsten, S., Hanganu, J., Kolada, A., van den Berg, M., Poikane, S., Phillips, G., Willby, N. and Ecke, F. (2008). Classifying aquatic macrophytes as indicators of eutrophication in European lakes. Aquat. Ecol., v.42(2), pp.237– 251. doi:10.1007/s10452-008-9182-y.
Pilgrim, G.E. (1934) Correlation of fossiliferous section in upper Cenozoic of India. Amer. Mus. Novit, v.704, pp.1–5.
Ranga Rao, A., Agarwal, R.P., Sharma, U.N., Bhalla, M.S. and Nanda, A.C. (1988). Magnetic polarity stratigraphy and vertebrate palaeontology of the Upper Siwalik Subgroup of Jammu Hills, India. Jour. Geol. Soc. India, v.31(4), pp.361–385.
Saber, A.A., Gontcharov, A.A., Nikulin, A.Y., Nikulin, V.Y., Rayan, W.A. and Cantonati, M. (2021). Integrative Taxonomic, Ecological and Genotyping Study of Charophyte Populations from the Egyptian Western-Desert Oases and Sinai Peninsula. Plants, v.10, pp.11-57. https://doi.org/10.3390/plants10061157
Sahani, B. (1936). The Karewas of Kashmir. Curr. Sci., v. **5**, pp.10–16.
Sahani, M.R. and Khan, E. (1959). Stratigraphy, Structure and Correlation of the Upper Shivaliks east of Chandigarh. Jour. Palaeontol. Soc. India, v.4, pp. 61-74.
Schneider, S.C., Nowak, P., von Ammon, U. and Ballot, A. (2016). Species differentiation in the genus Chara (Charophyceae): considerable phenotypic plasticity occurs within homogenous genetic groups. Europ. Jour. Phycol., v. 51(3), pp.282–293.doi:10.1080/09670262.2016.1147085.
Soulié-Märsche, I. (1982). Decouverte due genre *Nitellopsis* (Charophytes en Afrique) *Cabiers de Micropalaeontologie.* v.2, pp.111-122.
Soulie-Marsche, I. (1989). Etude comparee de gyrogonites de charophyteactuelesetfossiles et phyolgenie des genres actuelles. Edition Revise These Universite Montpellier 1979. Imprimeriedes Tilleuls Millau, France.
Soulie-Marsche, I. (1991). Charophytes as lacustrine biomarkers during the Quaternary in North- Africa. Jour. Afric. Earth Sci., v.12, pp.341-351.
Soulié-Märsche, I. (1993). Diversity of Quaternary aquatic environments in Northeast Africaas shown by fossil charophytes. In: U. Thorweine and H. Schandelmeier.
Soulié-Märsche, I. (1994). The Paleoecological Implications of the Charophyte Flora of the Trinity Division, Junction,Texas. Jour. Paleontol., v. 68 (5), pp. 145-1157.
Soulié-Märsche, I. (1999). Extant gyrogonite populations of Charazeylanica and Charahaitensis: implications for taxonomy and paleoecology. Austral. Jour. Bot., v.47, pp. 371-382.
Subramanian, D. (2002). Monograph on Indian charophyta. Dehra Dun (India): Bishen Singh Mahendra Pal Singh.
Suneja, I.J. and Singh, G. (1979a). On the occurrence of microfossils at the Khanpur Formation (Jammu and Kashmir). Sci. Cult., v. 45, pp. 77.
Suneja, I.J. and Singh, G. (1979b). First record of Charophyta from Tawi valley, Jammu and Kashmir. Indian Jour. Earth Sci., v. 6, pp.18.
Suneja, I.J., Singh, G. and Chopra, S.R.K. (1980). A note on the occurrence of microfossils in the Tawi valley sediments of Jammu and Kashmir and their stratigraphic significance. Proc.VII Indian Colloq. Micropalaeontol. Stratigr., pp.443-445.
Tambareau,Y., Gruas-Cavagnetto, C., Feist, M. and Vilatte, J. (1991). Flores et faunes continental esllerdiennes du versant sud de la Montagne Noire et de la Montagne d Alaric. Rev. Micropalaeontolog., v.34(1), pp.69-89.
Tewari, B.S. and Sharma, S.P. (1972). Some fossil Charophyta from Upper Siwalik near Chandigarh, India. Bull. Ind. Geolog. Assoc., v.5, pp.1-22.
Tewari, B.S. and Natarajan, C. (1978). Occurrence of charophytes in the Upper Karewas of Kashmir. Bull. Ind. Geolog. Assoc., v. 11(1), pp.87.
Verma, B.C., Mishra, V.P. and Gupta, S.S. (2002). Pictorial catalogue of Siwalik vertebrate fossils from Northwest Himalaya. Geolog. Surv. India, v.**5**, pp.1-378.
Wood, R.D. (1965). Monograph of the Characeae*. In* R.D. Wood, K Imahori, editors. Are vision of the characeae (Vol. 1). Weinhein (Germany): Verlag J. Cramer; pp. 1–904. doi:10.1007/BF00017575.
Zalat, A.A., Al-Wosabi, M.A., El-Sheekh, M.M. and Al-Subbary, A.K.A. (2020). New Record of Charophytes (Characeae, Charophyta) from Socotra Island, Indian Ocean, Yemen. Thalassas, v. 36, pp.437–445. https://doi.org/10.1007/s41208-020-00245-5