Recent advances in studies on fossil Charophyta

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Bhatia SB 1992. Recent advances in studies on fossil Charophyta. *Palaeobotanist* **40** : 413-419.

The main objective of the paper is to give a synoptic review of the more recent works on fossil Charophyta from India, particularly of those that have been published since the last review entitled "Post-Palaeozoic fossil charophyta of India" published in 1982 (Bhatia, 1982). The study of fossil Charophyta in India has remained largely neglected since the first fossil gyrogonite, *Chara malcolmsoni*, was described (Sowerby, 1839). It is only during the last two decades that the study of fossil charophytes has received a sudden impetus. Although, there is no record of Palaeozoic charophytes from India, the Mesozoic and Cenozoic charophytes are now much better documented.

Key-words—Fossil charophytes, Characeae, Deccan Intertrappean beds.

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सारांश

अश्मित केरोफ़ाइटीयों के अध्ययन में प्रगति

एस० बी० भाटिया

इस शोध-पत्र का उद्देश्य भारत से अश्मित केरोफ़ाइटी पौधों पर हाल में किये गये अध्ययन की समीक्षा करना है विशेषतया वे परिणाम जो कि भाटिया (1982) द्वारा प्रकाशित एक समीक्षात्मक शोध-पत्र के बाद सामने आये हैं। भारत में सोवरबाई (1839) द्वारा प्रकाशित अश्मित गाइरोगोनाइट—**कारा माल्कॉल्मसोनाई**, के अभिलेख के पश्चात् अश्मित केरोफ़ाइटीयों पर कोई शोध-कार्य नहीं हुआ। अपितु पिछले दो दशकों में इन पर अनुसंधान कार्य किया गया है। यद्यपि अश्मित केरोफ़ाइटीयों का पुराजीवी कल्प से कोई प्रमाण नहीं है, तथापि मध्यजीवी एवं नूतनजीवी केरोफ़ाइटीयों के पर्याप्त प्रमाण हैं।

OLDEST REPRESENTATIVE OF THE FAMILY CHARACEAE

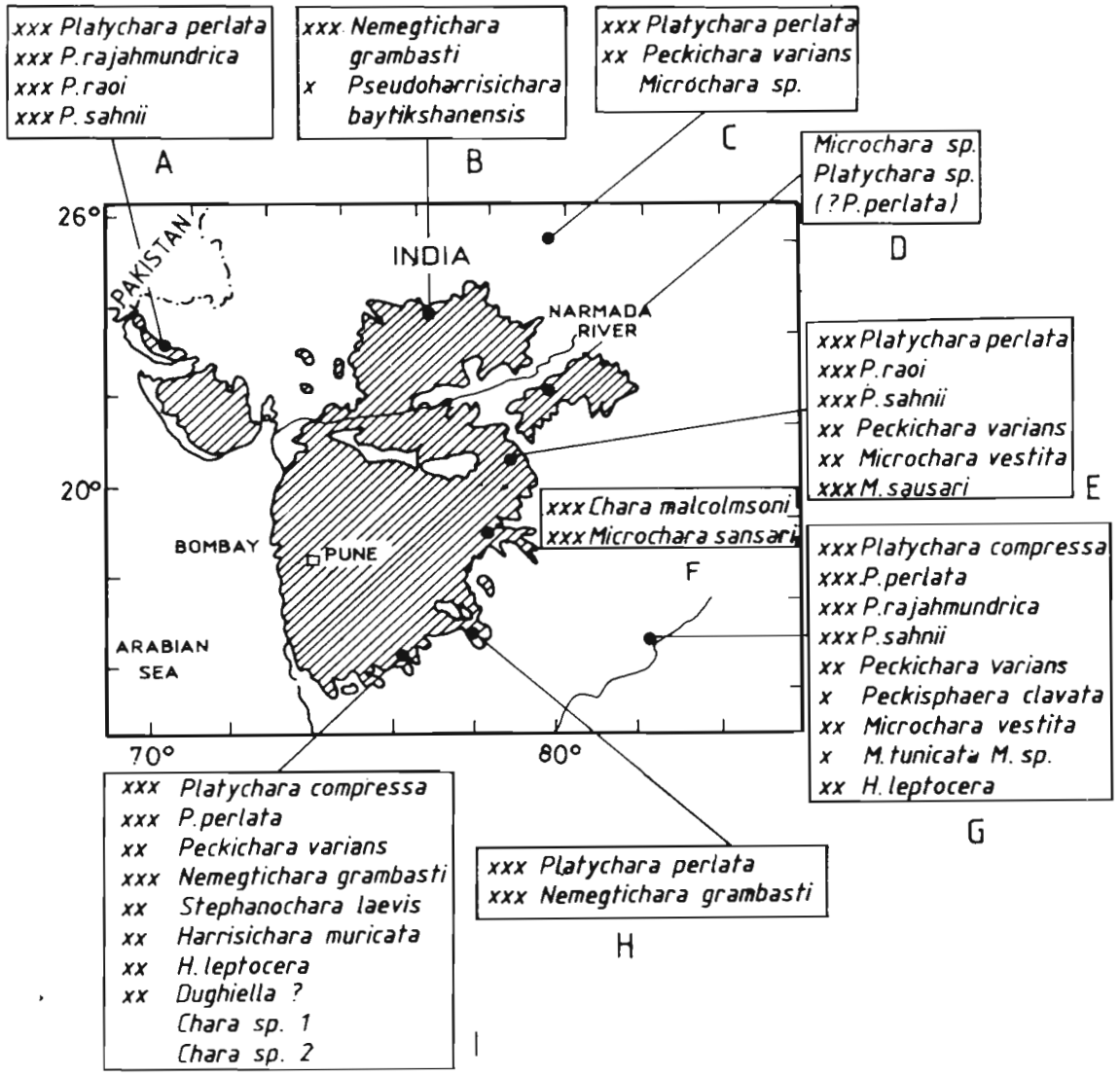
THE lacunae in our knowledge about Mesozoic charophytes, particularly the lack of any serious effort on the part of palaeobotanists in India to look for and study charophytes in the thick pile of non-marine sediments of the Gondwana Group has to some extent been filled now by the discovery of the oldest representative of the family Characeae, *Aclistochara* aff. *A. jonesi* Peck, in the Liassic freshwater Kota Formation, peninsular India (Fiest *et al.*, 1991). This significant paper which followed the first report of the occurrence of charophytes in the Kota Formation (Datta *et al.*, 1978), besides dealing with the taxonomy and phylogeny of the taxon, also deals at length on the possible palaeoecological implications of the charophytes and associated stromatolites and vertebrate remains. It is concluded that the charophytes lived in lime-mud sediments which were deposited in brackish water lakes with periodic oscillation of water level under arid conditions. The closure of apex by the ends of the calcified spiral cells, as in the case of *Aclistochara* aff. *A. jonesi* from Kota, is interpreted as a xerophytic structure allowing the plant to persist during intervals of dessication. The paper also demonstrates the increase of the average diameter of the apical pore of germination from *Porochara* to *Aclistochara* and *Lamprothamnium*.

DECCAN INTERTRAPPEAN CHAROPHYTES AND THE K-T BOUNDARY

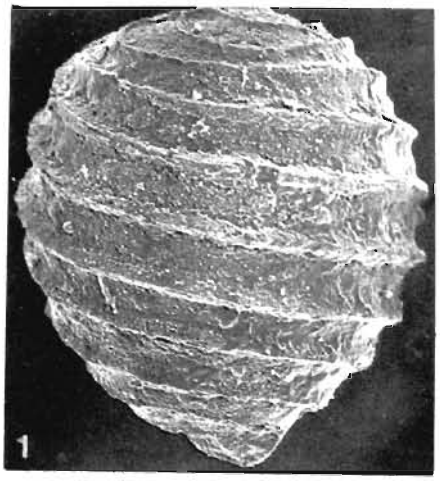
The maximum work on charophytes during the last two decades has been on the Intertrappean flora which is now thoroughly documented in terms of taxonomy, age implications and geographic distribution. The main contributions are by Mukherjee (1983) from the Infratrappean beds of Andhra Pradesh, Bhatia and Rana (1984) from

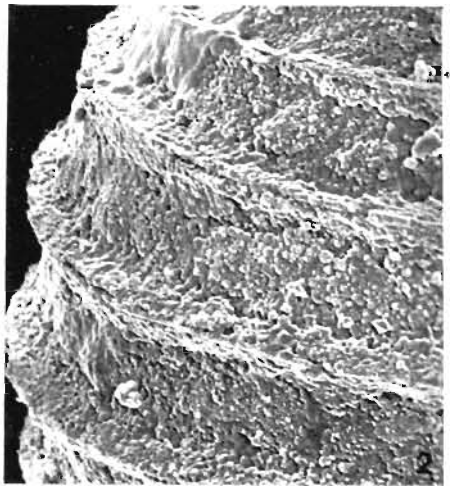
Four Decades of Indian Palaeobotany
Editors : B. S. Venkatachala & H. P. Singh
Publisher : Birbal Sahni Institute of Palaeobotany, Lucknow

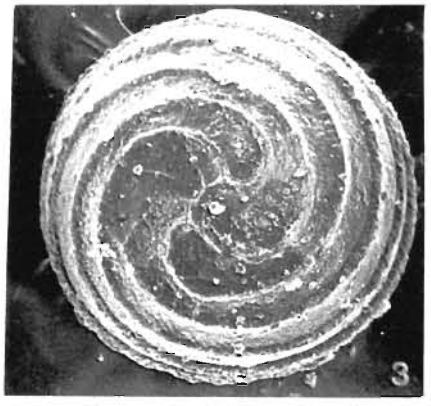
Nagpur, Bhatia *et al.* (1989) from Kutch, Chanda *et al.* (1989) from Rajahmundry, Bhatia *et al.* (1990a) from Rajasthan, Bhatia *et al.* (1990b) from Rangapur in Andhra Pradesh, and Srinivasan (1991) from Gurumatkal in Karnataka. The hitherto known distribution pattern of the various charophyte taxa from nine Intertrappean localities is graphically shown in Text-figure 1. The assemblage is represented by species belonging to the genera *Platychara, Peckichara, Harrisichara, Microchara, Nemegtichara* and *Chara* s. str. Of the various taxa, the species *Platychara perlata* (Peck & Reker) Grambast is the most ubiquitous, having been found in all the localities except Rajasthan. In Kutch, the flora is represented exclusively by four species of the genus *Platychara—P. perlata, P. rajahmundrica* (Rao & Rao, nov. comb. vide Bhatia *et al.* 1989), *P. raoi* Bhatia & Mannikeri and *P. sahnii* (Rao & Rao) Bhatia & Mannikeri. Of these, *P. perlata* is a cosmopolitan taxon and is known to range from Late Cretaceous to Palaeocene. The other three species appear to be endemic to this region. Contrary to the view of Chanda *et al.* (1989), *P. rajahmundrica* (= *Chara rajahmundrica* Rao & Rao) is a junior synonym of *P. compressa* (Knowlton), Bhatia *et al.* (1989) opined that *P. rajahmundrica* (nov. comb.) is a valid species. This is evident from the Isopolarity Index (ISI) of various species of *Platychara. P. rajahmundrica* which is strongly oblate in shape, has an ISI ranging from 64-69, whereas in *P.*

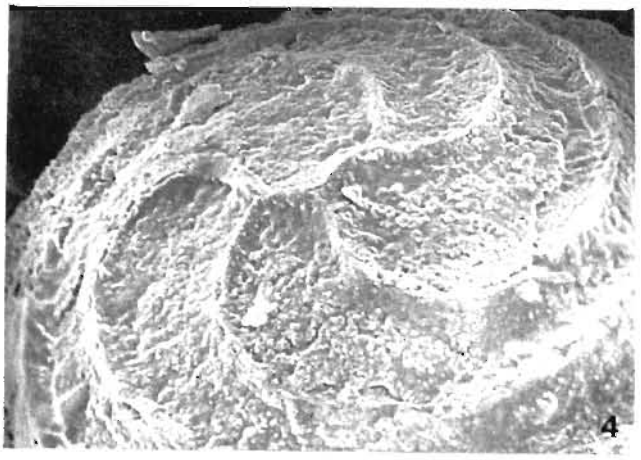


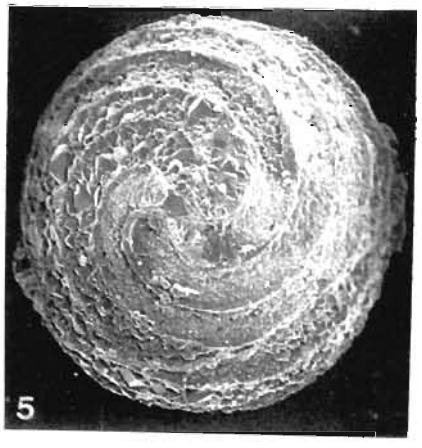
Text-figure 1—Showing geographic distribution of various charophyte taxa from the Deccan Intertrappean beds. Data is after various authors: **A**—after Bhatia *et al.* (1989); **B**—after Bhatia *et al.* (1990a); **C**—after Singh (1980); **D**—after Udoji and Verma (1990); **E**—after Bhatia and Mannikeri (1976) and Bhatia and Rana (1984); **F**—after Bhatia, 1982 and present work; **G**—after Bhatia (1982) and Chanda *et al.* (1989); **H**—after Bhatia *et al.* (1990b); and **I**—after Srinivasan (1991).











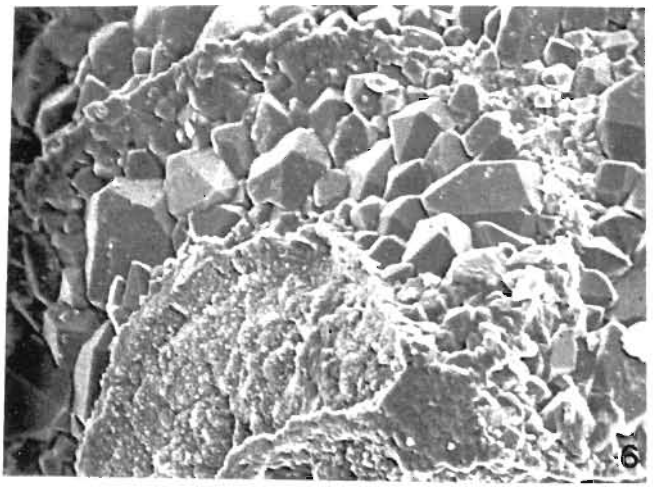


PLATE 1

Chara malcolmsoni Sowerby .
1, 2 Lectotype, lateral views 1, × 90; 2, × 240

3, 4 Paralectotype I, apical views. 3, × 83; 4, × 240.
5, 6 Paralectotype II, basal views. 5, × 90; 6, × 370.

compressa it ranges from 71-75. *P. raoi* and *P. sahnii* also occur in the Intertrappean beds at Nagpur (Bhatia & Rana, 1984), while *P. sahnii* occurs at Rajahmundry.

Peckichara varians Grambast, which was first reported by Bhatia (1982) from the Kateru Intertrappean, is now also recorded from Lalitpur, Nagpur and Gurumatkal. The genus *Nemegtichara* which was hitherto known only from Mongolia and China, is now represented in India by *N. grambasti* Bhatia, Riveline & Rana, from Rangapur in Andhra Pradesh (Bhatia *et al.*, 1990b) and from Gurumatkal (Srinivasan, 1991). The genus *Harrisichara* is represented by two species—*H. leptocera* Grambast and *H. muricata* Grambast-Fessard, both Palaeocene species and significantly restricted to Gurumatkal locality.

The only Late Cretaceous taxa in the Intertrappean beds are *Pseudoharrisichara* cf. *P. baytikshanensis* (Junying & Xinying) from Rajasthan (Bhatia *et al.*, 1990a) and *Peckisphaera clavata* Feist & Colombo and *Microchara tunicata* Grambast & Gutierrez, both from Rajahmundry (Chanda *et al.*, 1989). The genus *Stephanochara*, represented by the Palaeocene species *S. laevis* Massieux, has been reported by Srinivasan (1991). The genus *Microchara* is represented by *M. vestita* (restricted to Early Palaeocene) and *M. sausari* (Sahni & Rao) (vide Bhatia, 1982) which probably straddles the K-T boundary.

The genus *Chara* s. str. is represented by *Chara malcolmsoni* (herein redescribed) and two unidentified species from Gurumatkal (Srinivasan, 1991). *C. malcolmsoni* (Sowerby, 1839) has never been adequately described or illustrated. The illustrations by Sowerby are poor and no holotype was designated. Sahni and Rao (1943) who presumably had examined Sowerby's type slide did illustrate a specimen but its morphological characters have remained obscure. The assignment of this species to the genus *Mesochara* by Kyansep-Romashkina (1975) without any illustration or description has added confusion to its taxonomic status. Through the courtesy of the Keeper in Palaeontology, The Natural History Museum, London, the author was allowed to examine the type material of *C. malcolmsoni* Sowerby. The Type Slide (No. V/2 1472/10406, labelled *Chara malcolmsoni* Sowerby, Palaeocene-Eocene, Sichel Hills, central India) which was sent on loan to the author contained 17 gyrogonites, mostly badly preserved. No holotype had been designated. Through the kind permission of the Keeper, the author was allowed to select three better preserved specimens, apparently all silicified, to serve as Lectotype and Paralectotypes I and II (Pl. 1, figs 1-6—British Museum nos. V 63464 and V 63465, V 63466). The lectotype (Pl. 1, figs 1, 2) has 10 concave lime spirals, sharp raised spiral sutures and a protruding base. The lime spirals, which narrow considerably in width towards the apical periphery, expand again in width to meet at the apex along a wavy line (Paralectotype I, Pl. 1, figs 3, 4). The basal pore opening (Paralectotype II, Pl. 1, figs 5, 6) is small, polygonal in shape. This particular specimen shows silicified pseudomorphs of recrystallized calcite cystals in the vicinity of the basal pore opening.

Sahni and Rao (1943) who apparently had examined Sowerby's type material had correctly retained the species under its original nomenclature. Kyansep-Romashkina (1975) and Feist (personal communication, 1991) who have also presumably examined the type material, are of the opinion that the species be assigned to the Cretaceous genus *Mesochara* Grambast. Soulie-Marsche (1989) while discussing the characters of the genus *Chara* s. str. opined that even under an artificial classification, the characters of *Mesochara symmetrica* (Peck) Grambast (genotype of *Mesochara*) are comparable to those of *Chara setosa* Klein ex Willd. She concluded that the genus *Mesochara* is a junior synonym of the genus *Chara* s. str. and that the age of the genus *Chara* s. str. ranges from Cretaceous to Recent. The present description and illustrations of the lectotypes of Sowerby's type material show that the species belongs to the genus *Chara* s. str as redefined by Soulie-Marsche (1989).

An analysis of the stratigraphic ranges of the various charophyte taxa (Text-figure 1) shows that of the three definite Cretaceous taxa recorded, only *P. baytikshanensis* has been illustrated (Bhatia *et al.*, 1990a, pl. 1, fig. 13). The other two taxa, viz., *Peckisphaera clavata* and *Microchara tunicata* reported by Chanda *et al.* (1989), have neither been described nor illustrated so far and, therefore, their identity remains suspect. Majority of the Intertrappean charophyte taxa are either long ranging (Late Cretaceous to Palaeocene) or else restricted to the Palaeocene (Dano-Montian and or Sparnacian). The precise estimate of the age of the Deccan Volcanism or placement of the K-T boundary on the basis of charophytes, is therefore, possible only when the assemblage is associated with dinosaur remains or Cretaceous mammals, frogs and fishes (*vide* Sahni *et al.*, 1986; Prasad & Sahni, 1988; Prasad, 1989; Prasad & Rage, 1991) or with freshwater Maestrichtian ostracodes (Bhatia *et al.*, 1990c). The balance of evidence (based on stratigraphic ranges of Charophytes, palynofossils, dinosaurs, mammals, frogs and fishes) shows that

the Deccan Volcanism was a Late Cretaceous event, except perhaps for the Gulbarga District, where several definite Palaeocene charophytes taxa occur (data from Srinivasan, 1991, notwithstanding views expressed in Prasad & Srinivasan, 1990). These observations are in harmony with the overall palaeomagnetic and radiometric data and the more recent models and geological maps based on the geochemistry of the traps (Mitchell & Widdowson, 1991, among others) that the trap flows in the south and south-east are the youngest. It is likely that detailed bed-by-bed sampling of various Intertrappean sections in the Gurumatkal region and separation of the vertebrate, ostracode and charophyte bearing horizons may lead to a much finer biostratigraphic resolution and even to the precise placement of the K-T boundary in the region as it is here that the volcanism truly straddled the K-T boundary. An unidentified species assigned to the genus *Chara* has been reported from the Niniyur Formation (Palaeocene) Ariyalur, Tamil Nadu by Nath (1989).

EOCENE CHAROPHYTES

The occurrence of charophytes in the Lower-Middle Eocene sequence of the Subathu Formation in the Simla Hills was first reported by Mathur (1979) who recorded two taxa—*Harrisichara* from Zone III (= Ypresian) and *Gyrogona* from Zone VIII (= Lutetian). The bad state of preservation obviously precluded precise specific identification. However, a comparatively well-preserved suite of charophytes has recently been discovered by Bhatia and Bagi (1989, 1991) from the Red beds (Early Lutetian) of the Subathu Formation in the Koshalia River Section of the Lesser Himalayas. The assemblage includes three taxa—*Raskyella feisti, Stephanochara massieuxi* (both new species) and *Stephanochara* cf. *S. rochettiane* Heer. Both these genera are being reported for the first time from India. Biostratigraphically these charophyte gyrogonites occur in Zone IX of Mathur (1978) and Passage beds (*Sensu* Bhatia & Mathur, 1965). The assemblage, though new, shows affinities with the European Eocene taxa.

NEOGENE-QUATERNARY CHAROPHYTES

Very little has been added to our knowledge of the Siwalik charophytes since the assemblage was first described in detail by Bhatia and Mathur (1978) and the taxonomy was brought up-to-date by Bhatia (1982). Bhatia and Mathur's contention that the genus *Grambastichara* Rantzien is a junior synonym of *Chara* s. str. is now widely accepted in the latest classification by Feist and Grambast-Fessard (1982) and by Soulie-Marsche (1989) in her emended diagnosis of the genus *Chara* s. str.

The preliminary work on the charophytes from the Lacustrine Karewa Group (Hirpur Formation) of the intermontane basin of Kashmir by Bhatia *et al.* (1985) is now being followed up in detail by Bhatia and Soulie-Marsche (Ms in preparation). Besides dealing with the palaeolimnology of the Hirpur Formation, they also propose to discuss the significance of the shape of the basal pore opening in *Nitellopsis (Nitellopsis) obtusa* and *Lychnothamnus barbatus*. They have also recorded an unusual occurrence of stomata-shaped protrusions at sutures of lime spirals in *N. (N.) obtusa*, similar to the one recorded by Maslov from the Quaternary of U.S.S.R.

The Quaternary charophytic flora of the Indo-Gangetic Plain has been taken up for detailed study by Bhatia and Singh (1988, 1989). The former paper deals with a detailed chronology of Middle Holocene palaeoclimatic and palaeoecological events in southern Haryana. The charophytic flora is represented by *Chara aspera* and *Lamprothamnium* cf. L. *papulosum*. Both these species are ecologically significant as they are known to thrive best in permanent brackish water habitat. On the basis of the charophytic flora and the associated ostracode and foraminiferal fauna, they have postulated the occurrence of a lacustrine episode (Ca 5363 ± 110-3640 yrs B.P.) in southern Haryana during which extensive marl deposits were laid down in mesohaline lakes.

In contrast, the Quaternary charophytic flora from homotaxial beds in Uttar Pradesh (Bhatia & Singh, 1989) is represented by six taxa—*Chara aspera* Deth. ex Willdenow and its monoecious equivalent *Chara globularis* Thuillier, *Chara pappii* Soulie-Marsche. *Chara* sp. (ex. grp. *C. fibrosa*), *Lychnothamnus barbatus* Mayen (Vileon), and *Lychnothamnus* sp. (? new species). Of the above taxa, *Chara pappii* and *Lychnothamnus* sp. have been reported for the first time in fossil state from India. *Chara pappii* which was first recorded from the Upper Pliocene of Greece, is also known from the Holocene lacustrine sediments of Mali in central Sahara (Soulie-Marsche, 1982) and of Sudan (Kropelin & Soulie-Marsche, 1991). The present fossil record from India, thus, not only extends its geographical extent, but also suggests the possibility of its migration from southern Europe since Late Pliocene times to Northern Africa and India in Middle Holocene times. Consequently, it is likely that its extant representatives may be found in India

or Africa. This view has recently been supported by Kropelin and Soulie-Marsche (1991).

The disjunct distribution of Early and Middle Holocene representatives of *Chara aspera* in central Sahara and India and of its extant representatives in Eurasia (including India) and North America confirms Proctor's contention (Proctor, 1980) that *C. aspera* constitutes the greatest apparent exception to the general rule regarding the restricted distribution of dioecious species of *Chara*. The Middle Holocene assemblages recorded by Bhatia and Singh (1988, 1989) are also known to occur in Holocene lacustrine deposits (Ca 7500-6500 yr B.P.) of Northern Africa (Soulie-Marsche, 1991).

ACKNOWLEDGEMENTS

The author is grateful to the Keeper, Palaeontology, The Natural History Museum, London for loan of Sowerby's type material and permission to select and describe lectotypes. He is further grateful to Drs Grambast-Fessard, Monique Feist and Ingeborg Soulie-Marsche of Montpellier for literature and fruitful discussions, and to Mr Srinivasan for permission to include data from his unpublished Thesis.

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