New occurrence of carbonaceous megafossils from the Meso-to Neoproterozoic horizons of the Vindhyan Supergroup, Kaimur - Katni areas, Madhya Pradesh, India

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The Vindhyan Supergroup of Central India is one of the few stratigraphic sequences of the world that has yielded definite Proterozoic fossils from its different horizons. Since the discovery of coiled depression of a megafossil resembling *Grypania spiralis* from the Rohtas Stage of the Semri Series (Lower Vindhyan; Beer 1919), only few records of such nature were made. The present paper deals with a new locality yielding well preserved carbonaceous megascopic remains from ~1000 Ma Rohtasgarh Limestone Formation of the Semri Group of the Vindhyan Supergroup exposed near Kaimur town and also from an existing locality near Katni in Madhya Pradesh. Apart from recording *Grypania spiralis* Walcott (Walter, Oehler & Oehler 1976) and *Grypania* sp. the paper also records a new genus *Phyllonia* and three species of *Chuaria* out of which two are new (*Chuaria gigantia* n.sp. and *Chuaria melanocentricus* n.sp.). A new evolutionary trend in Proterozoic carbonaccous remains is also inferred on the basis of the present study.

Key-words — Megafossils, Vindhyan Supergroup, Semri Series, Rohtasgarh Limestone Formation, Mesoproterozoic, India.

INTRODUCTION

EMPHASIS has lately been laid on the Precambrian metazoans in the light of developing concepts of the Proterozoic biosphere. The record of metaphytes from pre-Ediacaran horizons around the world has greatly enhanced our knowledge on the evolutionary scheme with its bearing on eukaryotic development and diversification of life. In the last two decades, several reports from around the world, namely USA, Canada, Scandinavia, China and India, have contributed significantly towards a better understanding of the metaphytic and metazoan evolution.

Perhaps the earliest record of Precambrian megafossils in the world dates back to the discovery of plant remains by Captain F. Dangerfield (1823, p.332) when he described the occurrence *"between the slaty fracture numerous vegetable remains or impressions of species of fern, appearing to be in a carbonized state"* in the *"fine grained yellowish brown sandstone-slate"* from Jiran (Jeerun) area near Nimach (Neemutch) in Madhya Pradesh, India. Possibly the limited knowledge about Precambrian life available at that time constrained the author to compare these fossils with known taxonomic entities (*"! vegetable remains* and *species of fern"*) only. This locality has later yielded definite carbonized remains belonging to *Chuaria, Tawuia* etc. (Jones 1909, Mathur 1982 and 1987). J. Hardie (1829, p.40) studied the sandstone and shales of Neemuch area and stated *"The specimen in question appeared to me, to be the impression of a portion of a cryptogamous plant"*. He again described (1829, p.45) *"Protruding into the calcareo-argillaceous substance described as separating the strata"*, are frequently observed numerous *"flattened, polymorphous, lobated mass"* from Bhander or Nimbahera limestone of the Vindhyan strata. He also figured three specimens showing organic remains which he was unable to refer with certainty to any particular genus. A careful scrutiny of the sketches indicates that possibly one of the figures shows *Chuaria* impression with sinusoidal folding and the other two show either ? *Tawuia* or ? *Grypania*. Eichwald (1854) later described ribbon-like films (*Laminarites antiquis-*

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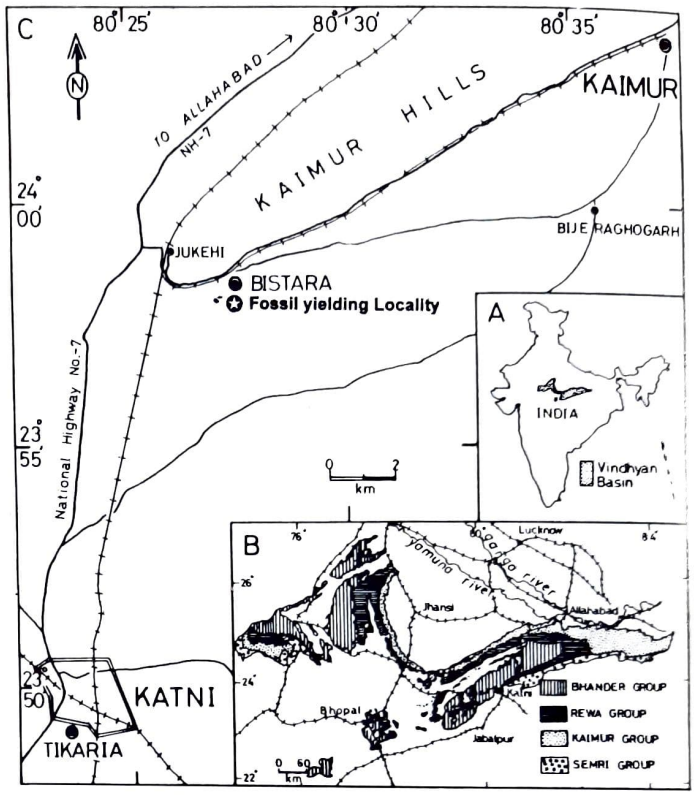
simus) from the Vendian of the East European Platform.

There have been several reports of megascopic carbonaceous remains from Mesoproterozoic to Neoproterozoic sediments of Cuddapah, Kurnool, Kaladagi, Bhima and Vindhyan basins. The first report of carbonaceous megafossils from the Kurnool sedimentary sequence (Owk Shale) dates back to King's (1872) report on peninsular India where he observed the occurrence of "*thin discoid bodies of about a sixteenth or an eighth of an inch in diameter, and generally of a dark brown color spread out on the surfaces of some of the laminae*". These were later found out to be *Chuaria circularis*. Recently, Kumar (1995) described the occurrence of such mega remains from the Katni area. The present investigation records additional information from the Katni area and also from a newly discovered area, which is about 24 km by road from Kumar's (1995) locality in Katni, near the town of Kaimur. The assemblage includes three genera and six species out of which one genus and three species are new. However, very recently Vibhuti Rai *et al.* (1997) discovered the *Chuaria - Tawuia* assemblage for the first time from the Upper Vindhyan sequence.

GEOLOGICAL SETTING

The Vindhyan Supergroup represents a thick sequence of sedimentaries distributed over a span of 1,66,000 sq. kms. in the central part of India, of which about 40,000 sq. km is concealed under the Ganga alluvium (Fig.1 A). The outcrops of the sequence occur in a patchy manner forming elevated hillocks and extended ridges on the peneplaned, generally flat terrains of the provinces of Madhya Pradesh, Uttar Pradesh, Bihar and Rajasthan.

The Vindhyan Basin was formed on two distinct tectonic terrains of the Indian Shield viz. the Bijawar Group and the Bundelkhand Granitic Complex. The Bijawar Group (Palaeoproterozoic age) and the Bundelkhand Granitic Complex form the basement for the Vindhyan sediments. The sedimentary successions of the Vindhyan basin are unmetamorphosed and show little deformation. The beds are generally horizontal to slightly dipping, with dips ranging from 3° to 10°. The basin is truncated on its north-western margin by the Delhi-Aravalli terrain (meta-sedimentary rocks)



Text-figure 1. Location map of the fossil yielding locality, A-Study area, B-Geological Map of Vindhyan Basin, C- Fossil yielding locality.

which strikes NE-SW. In the north, the sediments of the basin are concealed under the huge thickness of Indo-Gangetic alluvium and may extend in the Lesser Himalayan Mesoproterozoic to Neoproterozoic basins of Shali-Deoban-Krol Belt (Rai & Gautam 1998). In the east, the Vindhyan sediments are underlain by Palaeoproterozoic Bijawar Group and in the south-east they are truncated along the Satpura orogenic belt. In the south, they are overlain by the Deccan Trap basalts of Cretaceous age.

The lithostratigraphy of the Vindhyan Supergroup following Sastri and Moitra (1984), is grouped using the modern stratigraphic norms in Table 1.

The Vindhyan sequence is about 4000 m thick and is divided into two parts - the lower part constituting the Semri Group and the upper part constituting the Kaimur, Rewa and Bhander Groups (Fig. 1 B). The Semri Group is the thickest of all the groups. On the regional scale, the thickness varies considerably, however, the average thickness of various lithounits of the lower part of the Vindhyan sequence is given in Table-1.

Table 1. Lithostratigraphy (after Sastry & Moitra 1984) and radiometric ages of the Vindhyan Supergroup. (Names under parentheses represent Classification after Auden 1933). The radiometric dates are after, a-Srivastava and Rajgopalan (1988), b-Kreuzer *et al.* (1977) and c-Crawford and Compston (1970).

				(AFTER SASTRY & MOITRA) (1984)		(in Ma)		
PROTEROZOIC	VENDIAN	VINDHYAN SUPERGROUP	UPPER	BHANDER GROUP				
	RIPHEAN			REWA GROUP		— 710 +/- 120 [a] 700 +/- 120 690 +/- 125	145-250M	
				KAIMUR GROUP		— 890 +/- 40 [b]	50-350M	
			LOWER	SEMRI GROUP	ROHTAS SUBGROUP (ROHTAS STAGE)	BHAGWAR SHALE FM. ROHTASGARH LST. FM.	20-125M 200M	252M
					KHEINJUA SUBGROUP (KHEINJUA STAGE)	RAMPUR FM. SALKHAN LST. FM. KOLDAHA SHALE FM. — 1080 +/- 40 [b]	100-800M 90M 70-120M	1760M
					(PORCELLANITE STAGE)	DEONAR FORMATION	870-1525M	753M
					MIRZAPUR SUBGROUP (BASAL STAGE)	KAJRAHAT LST. FM. ARANGI FM. DEOLAND FM.	135-145M 280-460M 45-200M	510M
ARCHAEAN	BIJAWAR GROUP/ BUNDELKHAND GRANITIC COMPLEX 2400-2600 [c]							

REGIONAL CORRELATION AND AGE

The Vindhyans are considered to range in age from 1400 Ma to 600 Ma which indicates continuation of deposition from Mesoproterozoic to Neoproterozoic. Selective radiometric dates of few horizons of these sequences are given in the Table 1. This indicates that the Rohtas Subgroup falls in the age bracket of ~1100 to ~900 Ma and therefore ~1000 Ma can be taken as the tentative age of the fossil - yielding horizons.

Amongst the various Proterozoic basins of India, Trans-Aravalli Marwar Basin, Chattisgarh Basin, Kurnool Basin, Cuddapah Basin, Bhima Basin in the peninsula and Deoban-Shali-Krol Basin in the Himalaya, show deposition during Palaeoproterozoic to Neoproterozoic times. The closest dates from the lowermost part of Kaimur Group match very well with the Deoban Belt of the inner Lesser Himalayan carbonate belt (Jammu Limestone is dated as 967Ma by average model age of Galena; Raha *et al.* 1978). There are favourable indications (facies distribution pattern etc.) which strongly suggest that there was a close relationship between the Vindhyan Supergroup (lower part) and the Deoban Basin during their deposition and possibly the northern extension of Vindhyan Basin is represented in the form of Deoban Basin (in the Lesser Himalaya) which got detached during the various orogenic phases of the Himalaya, during the Tertiary times.

The Vindhyans were deposited on the peneplaned basement of the Bijawar - Bundelkhand group of rocks, with which a distinct unconformable contact is seen throughout. The

Vindhyan Basin shows the occurrence of its various stratigraphic lithounits in variable thicknesses being deposited on the basement giving rise to several offlap and onlap deposits. The general depositional trend is from east and northeast to west and southwest directions with the youngest horizons showing their maximum thickness towards the western margin of the basin.

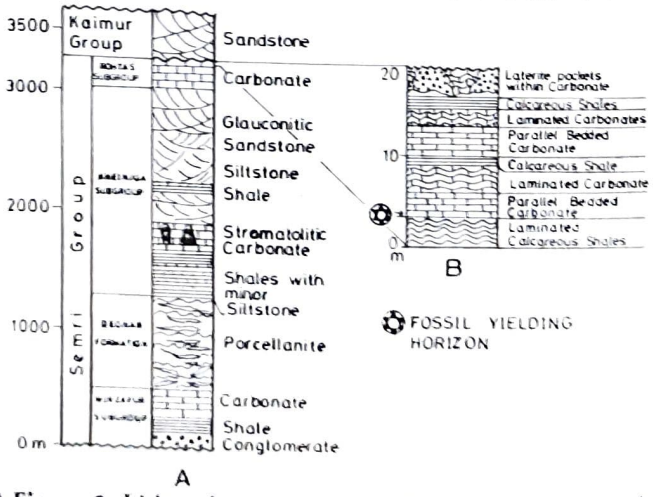
The stromatolitic assemblage of *Collenia, Stratifera, Kussiella, Conophyton, Colonella* and *Irregularia* from the Lower Vindhyan indicates Lower to Middle Riphean age which is comparable to *Collenia, Stratifera, Kussiella, Jurusania, Boxonia?, Baicalia* and *Masloviella* assemblage of the Deoban Group and its extensions in the Shali Belt of Himachal Himalaya as well as in the Inner Lesser Himalayan carbonate belt. The organic walled microfossils, acritarchs, etc. from bedded black chert layers of the carbonate sequences of these two basins show extreme similarity in the biota (Kumar & Srivastava 1992). Megascopic fossils of metaphytes and carbonaceous remains from the Deoban Basin (Rai & Gautam 1998) show close similarity between the two biota types.

FOSSIL YIELDING LOCALITY

In Katni and surrounding areas, rocks of the Rohtas Subgroup and the Kaimur Group are the dominant lithounits which are underlain by the Bijawar Group and overlain by the Deccan trap horizons. Scattered outcrops of the Vindhyan Group are exposed in the form of small hillocks and mounds with Kaimur Hills showing prominent relief in the form of an elongated ridge running NE-SW in the vicinity of Kaimur town. The Rohtas Subgroup contains high quality limestone and is being quarried all around Katni and the surrounding areas. These are open cast quarries where flaggy, light grey to cream coloured banded limestone occurs interbedded with shales. The limestone is of very fine quality (mostly micritic) and the interbedded shales have yielded the rich assemblage of carbonaceous megafossils. The earlier report of Proterozoic megafossil occurrence was from Tikaria (Kumar 1995), which is in the vicinity of Katni and the present newly discovered locality is near Bistara Village (lat. 23° 58′ 28" N, long. 80° 27′ 30" E) which is about 24 km from Katni and 17 Km from Kaimur by road (Fig. 1 C).

The present fossil - yielding sequence exposed near Bistara Village represents upper part of the Semri Group (Rohtas Subgroup) which is overlain by the Kaimur Group (Fig. 2 A). The lithological succession at one of the open cast mines shows that (Fig. 2 B) laminated calcareous shales dominate the sequence along with minor amounts of interlayered grey limestone horizons. The lower contact of Rohtas is not seen there as the succession is buried subsurface and only about 20 m of the succession is exposed in some of the open cast quarries (Fig. 3). A few scattered patches of limonite occur as massive masses overlying the limestones. Possibly the basaltic flows in the region have leached out and left their remnants over these limestones as massive bodies (Fig. 2 B). About 1 km northwards from Bistara, across the railway line, the Kaimur Sandstones overlie the Rohtas limestone sequence but the contact of the two lithounits is concealed under the alluvium.

A careful study of the limestone sequence shows that these were deposited under low energy realm. This is represented by flaser/ lenticular beds, current ripples, parallel undulatory beds and graded bedding. Not many subaerial exposure structures are seen (e.g., mud cracks, syneresis cracks, etc). Possibly the low energy domain might have given rise to favourable conditions where these megascopic algae (metaphytes) would have bloomed. The relatively slow rates of sedimentation with little influx of fine terrigenous clastics would have further enhanced their optimum preservable state where considerable details are



Text-Figure 2. Lithocolumn showing lithounits of the Semri Group (A) as well as detailed litholog in one of the limestone quarries exposed at Bistara village (B).

Text-Figure 3. South facing quarry at Bistara Village near Kaimur township showing bedded limestone/shale of the Rohtasgarh Limestone Formation yielding megafossils (marked by arrow).

preserved. The Rohtasgarh Limestone Formation representing low energy set up was transgressed by sudden influx of coarse clastics of the Bhander Sandstones with high energy depositional conditions indicating sudden change in the basin's tectono- sedimentary set up.

The carbonaceous megafossils described below are deposited in the Museum of the Geology Department, Lucknow University, Lucknow, India.

SYSTEMATIC DESCRIPTION

Group ACRITARCHA Evitt 1963

Genus ***Chuaria*** Walcott 1899; emend Vidal and Ford 1985

Type species : Chuaria circularis Walcott 1899

***Chuaria circularis* Walcott 1899**

Pl. 1, fig. h

[for Synonymy see Ford and Breed (1973), Maithy and Shukla (1984), Vidal and Ford (1985) and Sun (1987)]

Material - Pl. 1, fig. h; Figured specimen GDLU95V12.

Horizon & Locality - Rohtasgarh Limestone Formation, Rohtas Subgroup, Semri Group, Vindhyan Supergroup; Bistara Village, Kaimur area, Madhya Pradesh, India. (lat. 23° 58′ 28" N, long. 80° 27′ 30" E); 5 metres above the base of the quarry (marked by arrow in Fig. 3).

Description - Dark, compressed, carbonaceous discs preserved on the bedding surface with considerable variation in size ranging from minute specks to 5 mm in diameter. Most of the forms appear as mere specks which have coalesced randomly and formed an irregular network. Some discs show black shiny carbonaceous matter preserved in them, whereas others are generally light coloured but the presence of black, shiny matter in irregular patches or over the entire surface gives them different shades of brownish to dark grey colouring. Prominent wrinkles are not seen in the specimens. All these black shiny circular compressions are acid resistant.

Discussion - Chuaria has been widely studied by workers namely Ford and Breed (1973), Vidal (1974, 1976), Vidal and Ford (1985), Hofmann (1985a,b), Duan (1982), Sun (1987), Butterfield *et al.* (1994) and others. Many views have been given regarding its taxonomic position, based on preservational morphology. On the basis of its large size, Ford & Breed (1973) placed it under acritarchs comparable to Leiosphaerids. Gussow (1973) regarded it as spherical, planktonic organism, probably a cyst or spore sac, with soft outer membrane. He suggested that during compaction and deposition the outer surface became wrinkled. Sun (1987) described the form as spheroidal colonies of cellular filamentous cyanobacteria with spheroidal to elongate macroscopic bodies. He observed uniseriate, unbranched, densely compact tangle of filaments within these discoid, carbonaceous, compressed bodies. He also found some compressions containing one to several circular ring-shaped

bodies, darker than the surrounding discoidal area. He compared these forms to the living blue-green genus *Nostoc*. However, this view does not hold good as *C. circularis* has a thick, sturdy sporopollenin-like organic wall (Eisenack 1966) as reflected by the well preserved forms. *Nostoc* on the other hand has a thin layer which is unlikely to be preserved. The filamentous features observed by Sun (1987) may be due to mechanical and chemical degradation (Vidal 1974, 1976) which give pseudo morphologic characters to the form. Hofmann (1977) considers this genus to comprise a variety of groups including planktonic algae and also possibly medusoids. Butterfield *et al.* (1994) regard *Chuaria* as *"... a hollow organic-walled spheroid of unknown but probably algal affinities, i.e. an acritarch"*. Currently, most megascopic spheroidal forms of uncertain affinity are being placed within this genus. *Chuaria*, however, can be distinguished by its thick, opaque and psilate walls, absence of outer sheath and presence of concentric wrinkles and folds. Vidal and Ford (1985) considered it a single-walled genus, as is apparent in hand specimens. However, SEM and TEM studies reveal the wall to be a multilamellar strucutre (Amard 1992). The number and thickness of lamellae depend on biological factors such as growth and ecological factors such as depositional environment, eutrophication, etc. TEM study conducted by Jux (1977) shows a *"fine network, trabecular ultrastructure of the wall"*. The wrinkles may be due to shrinkage on drying or crushing during compac-

Plate 1

(Scale in all the figures is equal to 1 cm)

a. *Chuaria gigantia* sp. nov., GDLU95V08 (holotype); dark coloured, carbonaceous, circular form not bound by any definite outline but occurring as an aggregate of minute dark particles which are so arranged as to form a circular mass. The diameter of the form is 10 to 11 mm. The aggregate of particles give the circular form a speckled appearance. The form is surrounded by particles of dark carbonaceous matter occurring randomly over the bedding surface as individual specks, coalesced in linear chains or as irregular clusters. b. *Chuaria gigantia* sp. nov., GDLU95V04; dark, carbonaceous, compressed, circular form of diameter 12 mm. Slight protruberance can be seen on the left side of the specimen where diameter increases to 14 mm. The boundary is slightly irregular or wavy. The surface exhibits wrinkling. Dark matter occurs in an irregular manner over the bedding surface, surrounding the circular form. c. *Chuaria gigantia* sp. nov., GDLU95V05; compressed, circular, carbonaceous form with an irregular or wavy outline. Surface shows concentric wrinkles. Diameter of the form is 15 mm. A dark ellipsoidal body (greater diameter - 2.5mm and smaller diameter - 1.5 mm) is present on the surface of the specimen. The specimen is completely surrounded by darker (black) carbonaceous matter. d. *Phyllonia bistaria* gen. *et* sp. nov., GDLU95V10 (holotype); The sample shows four dark brown carbonaceous, spatulate forms, separated at broad ends and overlapping at the narrow ends. The width of the broad flat ends is 7mm to 12 mm while the length of the specimens ranges from 31 mm to 22 mm. The specimen on the extreme left is probably the first to be preserved over which the other two specimens were subsequently preserved. The fourth specimen is preserved in an inclined position with respect to the other three, with the narrow end overlapping the first specimen and the broader end merging with the narrower parts of the other two. Possibly a fragment of a fifth specimen is also preserved near the top merged ends. e. *Grypania* sp., GDLU95V01; a large sized brownish-grey, compressed, 'C' shaped filament. The margins are slightly wavy due to which the width of the filament varies between 3.5 to 4 mm. External diameter of the 'C' shape ranges between 24 to 25mm while the internal diameter of the 'C' shape varies only slightly from 18 to 18.5 mm. Terminal ends are rounded. Dark and light coloured areas can be seen on the filament indicating a possibly septate nature. These areas are not sharply demarcated and merge with the texture of the compression. f. *Grypania spiralis* (Walcott) Walter, Oehler & Oehler 1976 (emend. Walter, Rulin & Horodyski 1990), GDLU95V02; partly preserved, grey coloured, compressed, 'C' shaped, septate filament of width between 1 to 1.5 mm. External diameter of the 'C' shape is 15.5 mm while the internal diameter is 14 mm. The filament is not bound by any wall or sheath at the septate end. The other end occurs as a continuous filament with no septa preserved. The terminal end is rounded. The cells or empty spaces between two adjacent septa are wider than long. The length of the septa is 1 mm while the distance between two adjcent septa is about 0.5mm. Several yellowish to dark brown coloured specks and circular, compressed structures with diameter between 0.5 to 1.5 mm are seen in and around the 'C' shaped filament. A 3mm long and 0.5mm wide fragment of a filamentous form is also occurring near the edge of the specimen, in the upper part. g. *Phyllonia bistaria* gen. *et* sp. nov., GDLU95V09; this form is a counterpart of the one in Plate 1, fig. d. Here the specimens 1 and 3 are well preserved but specimens 2 and 4 are not clearly preserved. h. *Chuaria circularis* (Walcott) Vidal & Ford 1985, GDLU95V12; dark, compressed, carbonaceous discs preserved on the bedding surface. These discs are of variable sizes ranging from minute specks to 5mm in diameter. A number of these circular discs (5 measured) are 3mm in diameter. Most of the forms appear as mere specks which have coalesced together randomly and form an irregular network. The discs are generally light coloured but the presence of black, shiny matter in irregular patches or over the entire surface gives them different shades of brownish to dark grey colouring. i. *Chuaria melanocentricus* sp.nov., GDLU95VT1 (holotype) (upper specimen), GDLU95VT2 (lower specimen); circular, compressed, dark brown, carbonaceous bodies with an irregular, wavy margin. Concentric wrinkling is observed on the surface of the discs. The central portion is distinctly separated from the rest of the form by its darker (almost black) colour. The margin of the central mass is wavy and some wrinkles too are seen in this portion. Specks and irregular clusters of light brown to dark brown shiny matter occur randomly on the bedding surface, surrounding the discs.

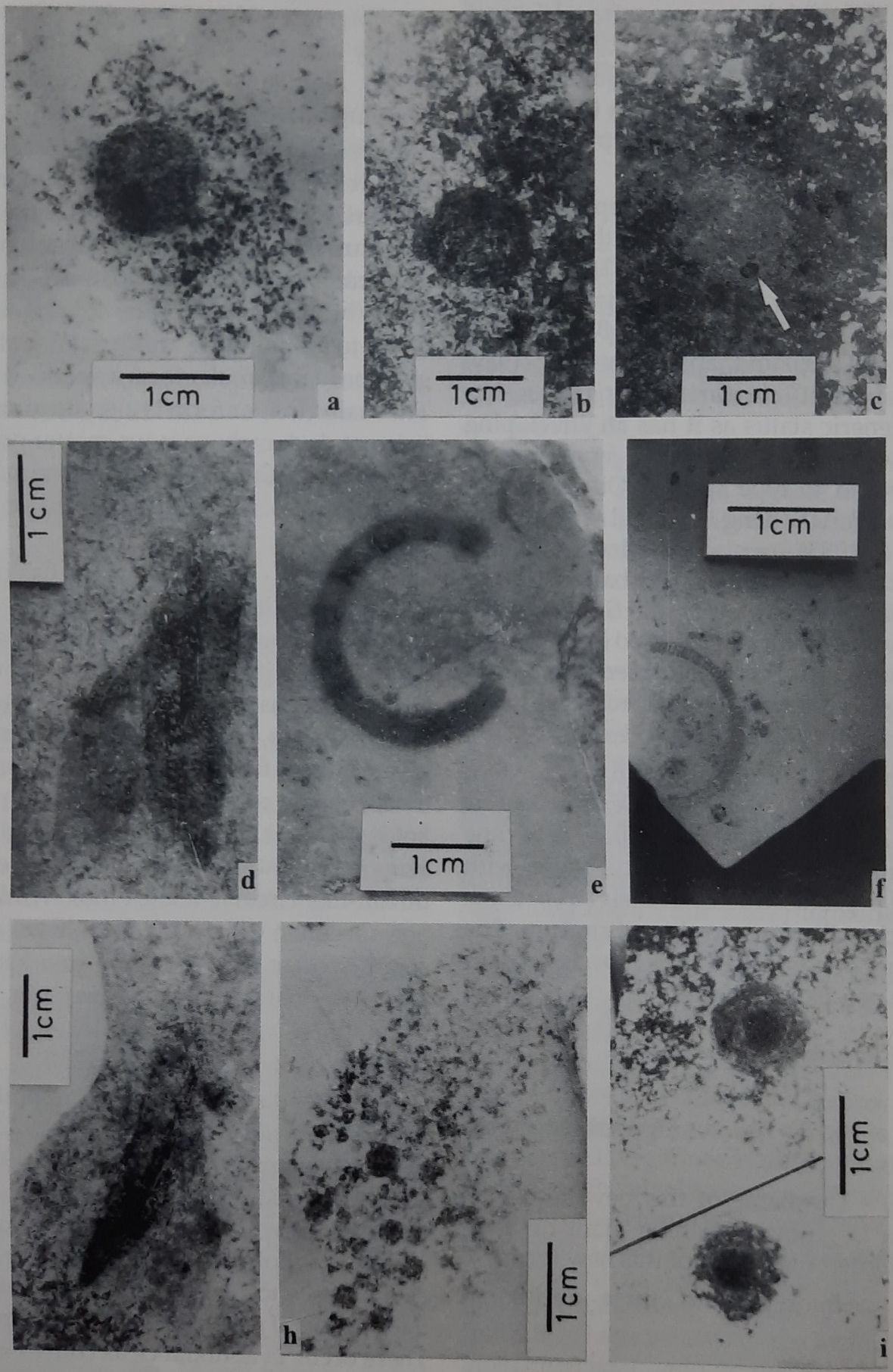


Plate 1

tion and preservation. The size range given by Ford and Breed (1973) as 0.5 to 5 mm is disagreed by Vidal (1974, 1976). Vidal's specimens from Visingsö Formation were in the size range of 0.09 to 0.2mm, going up to 3mm. Vidal and Ford (1985) included specimens as small as 70 microns in *C. circularis*. The upper size limit is generally accepted at 5 mm but the lower size limit is uncertain.

Chuaria was so far convincingly represented by only a single species - *C. circularis*, although other species like *C. wimani* (Brotzen 1941), *C. globosa* (Ogurtsova & Sergeev 1989), *C. fermorei* (Mathur 1983) have been described. Ford and Breed (1973), Vidal and Ford (1985) and Jankauskas *et al.* (1989) put *C. wimani* under *C. circularis*. *Chuaria globosa* has a doubtful generic status as it has an enveloping sheath unlike the type species. *C. fermorei* lacks folds as opposed to type species. Other species, namely, *C. annularis* (Zheng 1980) and *C. olavarriensis* (Baldis *et al.* 1983) are placed under C. *circularis* as they have been established on the basis of preservational variants only. Maithy and Shukla (1984) erected a new species *C. minima* based on difference in the exine structure. Since this observation could only be recognized in macerated specimens, it had limited utility in megascopic compressions.

The form shows similarity with the modern vesicular gametophytes of alga *Derbesia marina* belonging to division Chlorophyta (Bold & Wynne 1978). The gametophytes are spherical bodies with an elongated peg-like strucure at their base, which serves to anchor the form to the substratum. The analogy cannot be confirmed as our specimen does not show the peg-like structure.

***Chuaria gigantia* sp. nov.**
Pl. 1, figs. a-c

Holotype - Pl. 1, fig. a; Figured specimen GDLU95V08.

Etymology - The name of this new species is derived from *L. gigantis* meaning giant or huge which is attributed to the size of this new form.

Material - Holotype and three additional specimens.

Type locality - Rohtasgarh Limestone Formation, Rohtas Subgroup, Semri Group, Vindhyan Supergroup; Bistara Village, Kaimur area, Madhya Pradesh, India (lat. 23° 58′ 28" N, long. 80° 27′ 30" E); 5 metres above the base of quarry (marked by arrow in Fig. 3).

Diagnosis - Very large sized *Chuaria* with circularly arranged very fine network of threads besides abundant small carbonaceous specks bursting out of the main circular disc.

Description - Extraordinarily large sized, dark coloured, carbonaceous, circular form with faint marginal areas. Diameter varies from 10 to 11 mm. The form shows faint network of entangled threads occurring in a circular pattern, covered with black/brown carbonaceous aggregate of particles of 0.5 to 1.0 mm size and irregular shapes which give the main circular form a speckled appearance. The main circular form is also surrounded by particles of dark carbonaceous matter occurring randomly over the bedding surface as individual specks, coalesced in linear chains or as irregular clusters.

Discussion - The new species has been derived on the basis of its large size which goes up to 11mm. The known species till date are in the size range of 0.5 to 5mm with some forms being even smaller. Our specimens are almost double the size of any known species, hence a new specific name has been given to these forms. Sun's (1987) interpretation of *Chuaria* being compared with modern *Nostoc* balls holds good for *C. gigantia* as the circular compressions in present specimens do show well preserved thread-like circular bodies (not wrinkles). In fact one specimen (Plate 1c) also shows a number of small circular to oval bodies (marked by arrow) within the main circular compression, which could be daughter colonies originally enveloped within the main bodies (Sun 1987, p.122).

Another taxon with close resemblance to *C. gigantia* is *Beltanelloides* Sokolov 1972 (= *Beltanelliformis* Menner 1974 in Keller *et al.* 1974). *Beltanelloides* is considered for very large sized circular impressions with maximum disc diameter reaching up to more than 20 mm, having a pseudo resemblance to *Chuaria* in circular fold pattern at the peripheral part and without carbonaceous film. These occur in abundance as convex discoid casts with a flattened central portion and fine concentric rugae around the periphery (Sokolov & Iwnowski 1990). They differ from *C. gigantia* in composition.

***Chuaria melanocentricus* sp.nov.**

Pl. 1, fig. i

Holotype - Pl. 1, fig. i; Figured specimen GDLU95VT1.

Etymology - The name of the species has been derived from L. *melan* = dark and Gr. *centrum* = a point, a characteristic feature of the present form.

Type locality - Rohtasgarh Limestone Formation, Rohtas Subgroup, Semri Group, Vindhyan Supergroup; Tikaria Village near Katni, Madhya Pradesh, India (lat. 23° 51′ N, long. 80° 19′ E).

Material - One specimen in two counterparts. The two illustrated specimens represent the same specimen after being split into two portions along the bedding plane.

Diagnosis - Very large sized *Chuaria* with a dark circular disc in the central part.

Description - Circular, compressed, dark brown, carbonaceous body with an irregular and wavy margin showing concentric wrinkling throughout the surface of the discs. The outer diameter of the form varies from 9 mm to 10 mm. The central portion is distinctly separated from the rest of the form by its darker (almost black) colour which is about 3 to 4 mm in diameter. The margin of the central mass is wavy and some wrinkles are seen in this portion too. Specks and irregular clusters of light brown to dark brown shiny carbonaceous matter occur randomly on the bedding surface, surrounding the discs.

Discussion - This form is characterized by its large size and dark central disc. Sun (1987) described some compressions of *C. circularis* as having one or several tiny circular or ring-shaped flattened bodies inside which are darker than the surrounding area on the discoidal surfaces . Our specimens differ from these forms in that the central body is circular in shape and size range is much greater, being 3-4 mm, as compared to 0.1-0.5 mm of Sun's specimen. A few samples of *Chuaria* from Rampura, M.P. also show well developed dark central disc (Unpublished material and personal communication, Dr. Manoj Shukla, Birbal Sahni Institute of Palaeobotany, Lucknow).

Division: Phaeophyta (?), Rhodophyta (?) or Chlorophyta(?) or Cyanophyta (?)

Genus ***Grypania*** Walter, Rulin & Horodyski 1990.

Type species - *Grypania spiralis* (Walcott) emend. Walter, Rulin & Horodyski 1990.

***Grypania spiralis* (Walcott) Walter, Rulin & Horodyski 1990.**

Pl. 1, fig. f

Material- Pl. 1, fig. f; Figured specimen GDLU95V02.

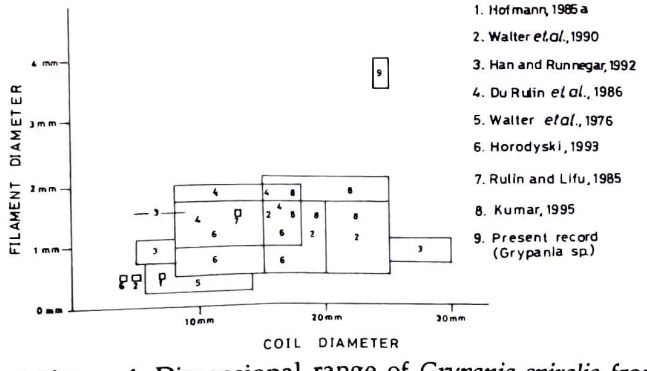
Horizon & locality - Rohtasgarh Limestone Formation, Rohtas Subgroup, Semri Group, Vindhyan Supergroup; Bistara Village, Kaimur area, Madhya Pradesh, India (lat. 23° 58′ 28" N, long. 80° 27′ 30" E); 5 metres above the base of quarry (marked by arrow in Fig.3).

Description - Partly preserved, grey coloured, compressed, 'C' shaped, septate filament of width between 1 to 1.5 mm. External diameter of the 'C' shape is 15.5 mm, while the internal diameter is 14 mm. The filament is not bound by any wall or sheath along its length towards one end, however, the other end occurs as a continuous filament with no septa preserved. The terminal end is rounded. The cells are disc shaped where the length is shorter than width. The length of the septa is 1 mm while the distance between two adjacent septa is less than or equal to 0.5 mm. Several yellowish to dark brown coloured specks and circular, compressed structures with diameter between 0.5 to 1.5 mm are scattered in and around the 'C' shaped filament. A 3 mm long and 0.5 mm wide fragment of a filamentous form is also occurring near the edge of the specimen, in the upper part, but is not shown in the illustrated figure. Counterpart of the specimen is also available.

Discussion - *Grypania* was first described by Walcott (1899) as trails of metazoans, namely, *Helminthoidichnites*. The oldest record is from 2.1 billion year old Negaunee Iron Formation, Michigan, USA, described by Han and Runnegar (1992). Walter, Rulin and Horodyski (1990) have recorded the form from 1400 Ma Greyson Shale of Belt Supergroup, Montana, USA and Gaoyuzhuang Formation of Changcheng System, Tianjin, China. In India, they have been recorded from about 1000 Ma Lower Vindhyan sequence of the Vindhyan Supergroup (Kumar 1995). The Indian occurrence was first recorded by Beer (1919) as an uncompacted form with circular cross-section. Tandon and Kumar (1977) described a form *Katnia singhii* from

the Katni assemblage, Madhya Pradesh, as belonging to Annelida. However, Runnegar (1991) placed this form along with that described by Beer (1919) under *Grypania spiralis*.

Grypania is characterized by its typical shape, large size, complex morphology and rigid structure. Based on these criteria, Han and Runnegar (1992) regarded it as probably a eukaryotic alga. Rounded terminations and transverse markings are often observed in these forms. Indian specimens often show well preserved features. Walter *et al.* (1990) believed these transverse markings to be a result of preservation of broken fragments, encased together within the sediments or degradational collapse of organic material contained within a coherent envelope. Although accepted as a megascopic alga with probable eukaryotic affinity, no definite taxonomic position has been assigned to this genus. Cyanobacterial and bacterial origins have been ruled out by Han and Runnegar (1992) on the basis of its large size and presence of coiling, rounded terminations and transverse markings respectively. Walter, Oehler and Oehler (1976) could not find a modern analogue to this form. Based on carbonaceous preservation they suggested it to be algal or higher plant material, not known in modern biota. Conway Morris (1989) considered *Katnia singhii* which was later placed under *G. spiralis* to be a brown alga. Walter *et al.* (1990) regard these forms as megascopic algae with a cylindrical thallus and a coiled habit. They are of the opinion that if the form is benthic then it should be comparable to extant sulfide oxidizing bacteria, *Thioploca*. The benthic nature of the form is not confirmed. Han and Runnegar (1992), however, considered *Grypania* to be photosynthetic algae.



Text-Figure 4. Dimensional range of *Grypania spiralis* from published records.

The scanty occurrence of *Grypania spiralis* from such geologically variable ages as well as widely distributed areas suggests that a natural experiment amongst the algal communities for gigantism was successfully accomplished by the organic world, where competition for space and necessity for growth were the main pressurer factors imposed by the natural selection in the early evolution of algal communities.

All views notwithstanding, no modern analogue has as yet been discovered or confirmed for this form. Hence, its position in the taxonomic hierarchy remains doubtful and therefore Han and Runnegar's (1992) comparison of *G. spiralis* with giant unicellular dasycladacean alga *Acetabularia* does not testify to its true lineage.

Grypania sp.

Pl. 1, fig. e

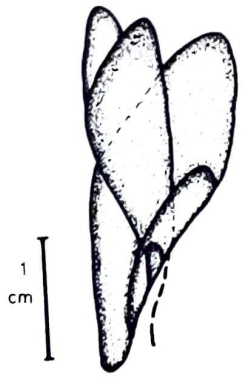
Material - Pl. 1, fig. e; Figured specimen GDLU95V01.

Horizon & Locality - Rohtasgarh Limestone Formation, Rohtas Subgroup, Semri Group, Vindhyan Supergroup; Bistara Village, Kaimur area, Madhya Pradesh, India (lat. 23° 58′ 28" N, long. 80° 27′ 30" E); 5 metres above the base of quarry (marked by arrow in Fig.3).

Description - A large-sized, brownish-grey, compressed, 'C' shaped filament with wavy margins due to which the width of the filament varies from 3.5 to 4 mm. External diameter of the 'C' shape ranges from 24 to 25mm, while the internal diameter is about 18.5 mm. The filament shows clotted dark portions all along its length and gives a superficial resemblance to septate structure.

Discussion - This is perhaps the largest known specimen of *Grypania* and looks very different from the earlier described forms in its occurrence. The closest resemblance of this form is with those described from the Jixian and Montana (Figure 4 B, J of Walter *et al.* 1990) where similar clotted dark parts along the length of the filament are also seen in the specimens. A diagrammatic representation of known reports of *Grypania* indicates that this particular occurrence is way apart from most of the known forms as far as size relationship is concerned (Fig. 4).

Division: Phaeophyta (?), Rhodophyta (?) or Chlorophyta(?) or Cyanophyta (?)



Text-Figure 5. Reconstruction of living stage of *Phyllonia bistaria*.

Genus ***Phyllonia*** gen.nov.
Pl. 1, figs. d, g

Type species - *Phyllonia bistaria* sp. nov. (Plate 1d, g)

Etymology - From the Greek *Phyllon*, leaf, with reference to the fossil's morphological similarity after compression.

Horizon & locality - Rohtasgarh Limestone Formation, Rohtas Subgroup, Semri Group, Vindhyan Supergroup; Bistara Village, Kaimur area, Madhya Pradesh, India (lat. 23° 58′ 28" N, long. 80° 27′ 30" E); 5 metres above the base of quarry (marked by arrow in Fig. 3).

Material - Two calcarous shale samples vide nos. GDLU95V09 and GDLU95V10 which are counterpart of each other.

Diagnosis - Dark, carbonaceous forms, spatulate in shape, i.e. broad at one end and narrowing at the other. The forms occur in a group with their broad ends free and narrow ends overlapping and merged, giving a radiating fan-like appearance.

Description - The spatula shaped individual forms occur in a bunch of clades with their width at broad end ranging between 7mm to 12mm. Length ranges between 22 - 31mm. Terminal ends not clearly seen in all the clades but one specimen shows a tapering, rounded terminal end.

Discussion - These forms are characterized by their typical spatula shape. The terminal narrow ends are not clear as they merge and overlap. However, one small specimen which lies inclined to the rest shows a tapering, rounded terminal end. The three clearly visible forms of the cluster are arranged radially with the broad ends free and spread-out and the narrow ends merging towards a central point. The lowermost form has a broad base protruding from below the other two forms. A fourth specimen inclined to the other forms and overlying them is also seen. On closer scrutiny, a smaller form with its narrow ends merging with that of other forms and broader part lying over fourth specimen is also seen.

This form is somewhat comparable to genus *Longfengshania* Du 1982 on the basis of its sub-radial arrangement. The broad ends may be broken parts of a whole specimen and the actual specimen may be elongate oval as in the genus *Longfengshania.* However, these forms differ from the type species in that they lack a stipe which characterizes the type species. Moreover, the size range of *Phyllonia* is at least twice than that of *Longfengshania.* A comparison of *Phyllonia bistaria* can also be made with *Lanceoforma* Walter *et al.* 1976. However, *Lanceoforma* is very small in size (1-2 mm wide and 9-10 mm long), carbonaceous and occurs as flat films. These are interpreted as thin, sheet like structures folded over on themselves. The mono type species *L. striata* has fine longitudinal striations on the surface as well. However, *P. bistaria* besides being very large, also shows typical spatulate shape with one broader end and another tapering end. There is no surfacial characteristic seen on the compressed forms unlike *L. striata.*

Although the forms seen in our sample are partially preserved, they show their morphological parts well developed. These forms may be rounded at their base, with the lower part being broken during preservation, giving a flat, spatulate shape to the forms. A reconstruction of the possible living habit of *Phyllonia bistaria* suggests that the form would be erect and attaches to substratum in bunches (Fig. 5). On this basis, *Phyllonia* can be compared to some modern algal forms. *Pterygophora californica* of Division Phaeophyta can be a modern analogue for *Phyllonia* as its single blade-like shape, growing from a woody stipe resembles that of *Phyllonia.* The analogy cannot be ascertained as our form does not show a stipe due to preservational constraints.

The present genus resembles with *Ulvaria obscura* and *Characiosiphon rivularis* both belonging to Chlorophyta. *Phyllonia* is comparable to the juvenile stage of *U. obscura* which is uniseriate, filamentous, with a rounded base. Similarly on the basis of morphological features it can be compared to *C. rivularis*, which is an elongate, cylindrical to clavate form with its narrow end attached to the

substratum. The form is also comparable to extant algae *Valonia ventricosa*, a club shaped Chlorophycean algal form (Bold & Wynne 1978). *V. ventricosa* is a multicellular form and has rhizoids protruding out from its lower surface which are not seen in our specimen. A definite analogy however, can not be ascertained as a completely preserved form is not yet found.

***Phyllonia bistaria* sp.nov.**

Pl. 1, figs. d, g

Holotype - Pl. 1, fig. d; Figured specimen GDLU95V10.

Etymology - The name is derived from Bistara Village from where this form is recorded for the first time.

Horizon & locality - Rohtasgarh Limestone Formation, Rohtas Subgroup, Semri Group, Vindhyan Supergroup; Bistara Village, Kaimur area, Madhya Pradesh, India (lat. 23° 58′ 28" N, long. 80° 27′ 30" E); 5 metre above the base of quarry (marked by arrow in Fig. 3).

Material - Two calcareous shale samples vide nos. GDLU95V09 and GDLU95V10 which are counterpart of each other.

Diagnosis and Description - Same as for the genus.

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