

Discovery of carbonaceous megafossils (*Chuaria-Tawuia* assemblage) from the Neoproterozoic Vindhyan succession (Rewa Group), Allahabad-Rewa area, India

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Well preserved carbonaceous compressions and impressions of Proterozoic mega algal assemblage *Chuaria circularis-Tawuia dalensis* are recorded for the first time from the upper part of the Rewa Group, Vindhyan Supergroup, exposed in an escarpment near the town of Allahabad on the Madhya Pradesh-Uttar Pradesh border. These millimetric-sized fossils represent an important event in the evolution of the Proterozoic biosphere. The significance of the present record indicates towards continuance of macro-organic community across the entire Vindhyan sequence. This aspect has been discussed in the light of previous records from India and abroad and its bearing on the age of the upper part of the Vindhyan succession and correlation of the sequence on a regional scale.

THE Proterozoic (2.50–0.54 Ga) biota contains the key to later diversification of life forms of the Phanerozoic. Despite being scanty and varied, the records of microfossils and megafossils of the Precambrian have helped the palaeobiologists to build an evolutionary scheme where events related with distinct diversification of life forms occur in a sequential order. These events mainly pertain to the evolution of prokaryotes and their later diversification to eukaryotes, evolution of mega-algal carbonaceous forms, evolution of the Ediacaran meganimals and the development of mineralized shell structures amongst the micro-organismic community. Another noticeable event is related with the size domain of the organic world during the Proterozoic, viz. evolution of macro-sized plan from an earlier microscopic domain.

We report here the occurrence of a well preserved *Chuaria-Tawuia* assemblage from the Jhiri Shale Formation of the Rewa Group, Vindhyan Supergroup of Peninsular India. Considering the earlier mentioned parameters of the Proterozoic evolution of the organic world, the present find assumes significance as carbonaceous mega remains represent a highly evolved community during the Neoproterozoic (1000–543 Ma). Although carbonaceous remains of possibly mega-algae are reported from 2.1 Ga (ref. 1), a few reports also exist from 1.8 to 1.7 Ga (refs 2,3) and 1.3 Ga (ref. 4). A sudden increase in diversity and density of the group shows its acme during the Neoproterozoic time span^{5,6}.

Chuaria-Tawuia represent a fossil assemblage under this carbonaceous category which occurs globally on a much wider scale. These carbonaceous remains are also known from the Proterozoic basins of India namely, the Vindhyan, the Bhima and the Kurnool. However, each basin has yielded such carbonaceous remains from just one stratigraphic horizon. In the Vindhyan basin, the newly discovered horizon occurs as the second level of carbonaceous mega-fossil yielding horizon, the first being the Semri Group^{9–13}.

The present find is from the road section (NH 27) joining Allahabad and Rewa near the village Sohagi (lat. 24°59' 00"N and long. 81°41'45"E), which is about 56 km from Allahabad (Figure 1). To the south of Sohagi, a prominent escarpment of the Rewa Group emerges from a rather flat terrain of the Gangetic alluvium. A well-developed sedimentary succession of the Rewa Group occurs at the ascent of the hill (Figures 2 and 3 a). The beds are usually flat with warping seen along the bedding plane.

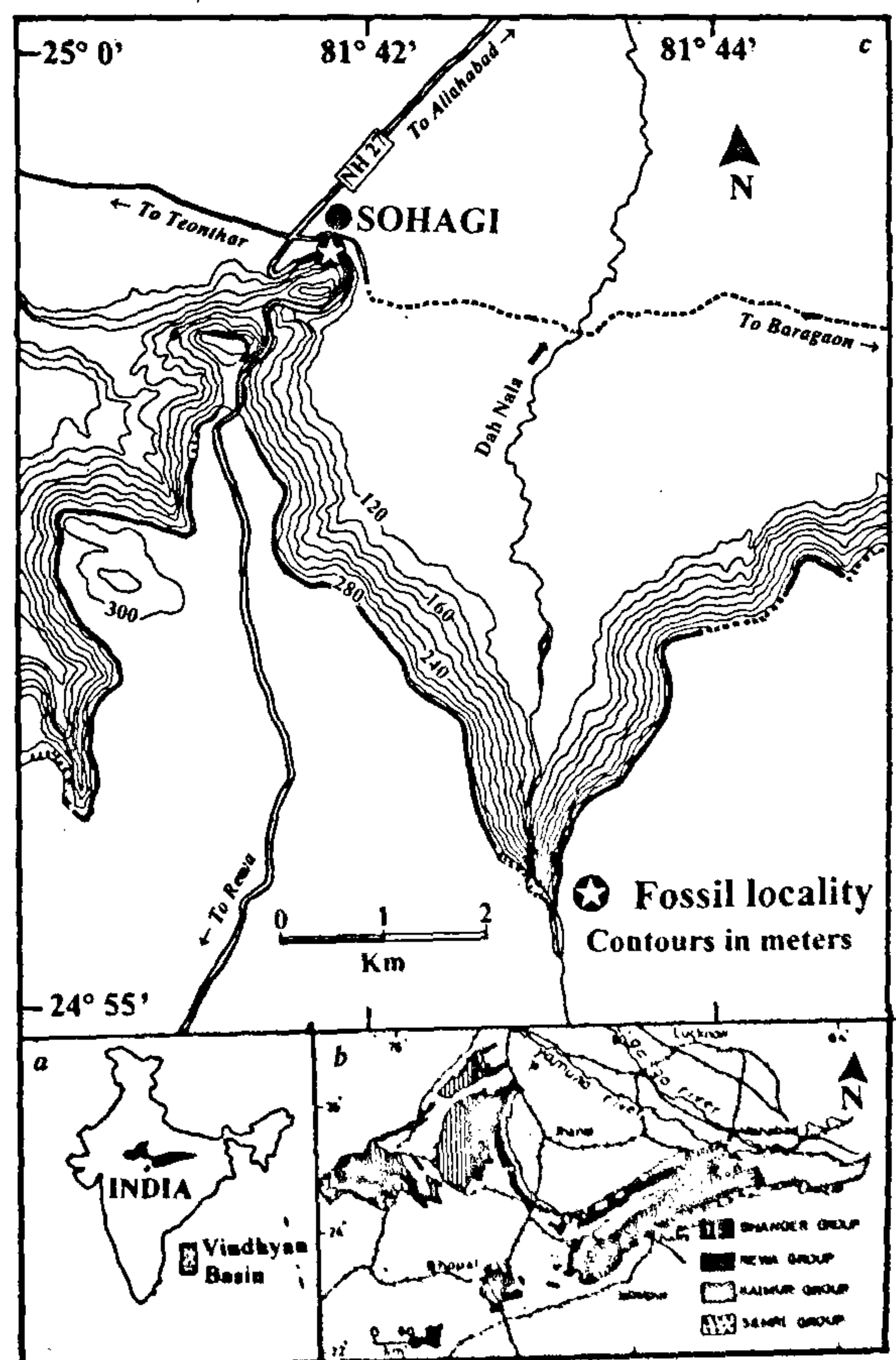


Figure 1. a, Study area. b, Geological map of the Vindhyan Basin. c, Locality map showing fossil yielding horizon.

The Vindhyan Supergroup has a fairly established lithostratigraphic succession (Table 1). On the basis of various geochronological dates, the succession seems to represent development from ~ 1.4 Ga to ~ 0.6 Ga. Reports on the occurrence of carbonaceous megafossil remains have been published from time to time from different areas and stratigraphic levels¹²⁻²⁰. These suggest a highly diversified community of algal groups during the lower Vindhyan time span. Narsimhan and Raju²¹, without assigning a name to their specimens, briefly described sub-circular, non-carbonaceous discs, with nearly 2 cm diameter, from the Jhiri (Jheeree) shales of the Rewa Group. Such large-sized forms are way beyond the size range of *Chuarina circularis* and possibly represent *Beltanelloides* or *Beltanelliformis*.

The present finding of the carbonaceous mega-fossils assumes importance as the new horizon yielding these remains is from a stratigraphically higher level of the succession in contrast with all earlier reports from the lower Vindhyan succession so far. The upper Vindhyan succession is represented by the Kaimur Group, the Rewa Group and the Bhandar Group in ascending order. The upper part of the Rewa Group is developed in siltstone and shale lithologies (Figure 2). The stratigraphy of the sequence under present study has been worked out for more than a century²². Banerjee and Sengupta²³ gave a detailed litho-section of Sohaghat and emphasized the source area of the sedimentaries of the Rewa Group and their possible depositional realm; Chakraborty and Chaudhuri²⁴ discussed the stratigraphy of the Rewa Group besides proposing a palaeogeographic reconstruction of the Vindhyan basin during its sedimentation. Volcaniclastic deposits from the Rewa Group of the Sohaghat section were also discussed in detail²⁵. The sequence of the Jhiri Shale Formation which has yielded well preserved *Chuarina-Tawuia* assemblage is made up of ferruginous, green to maroon coloured shale with occasional cream to grey-coloured layers (Figure 3 a)

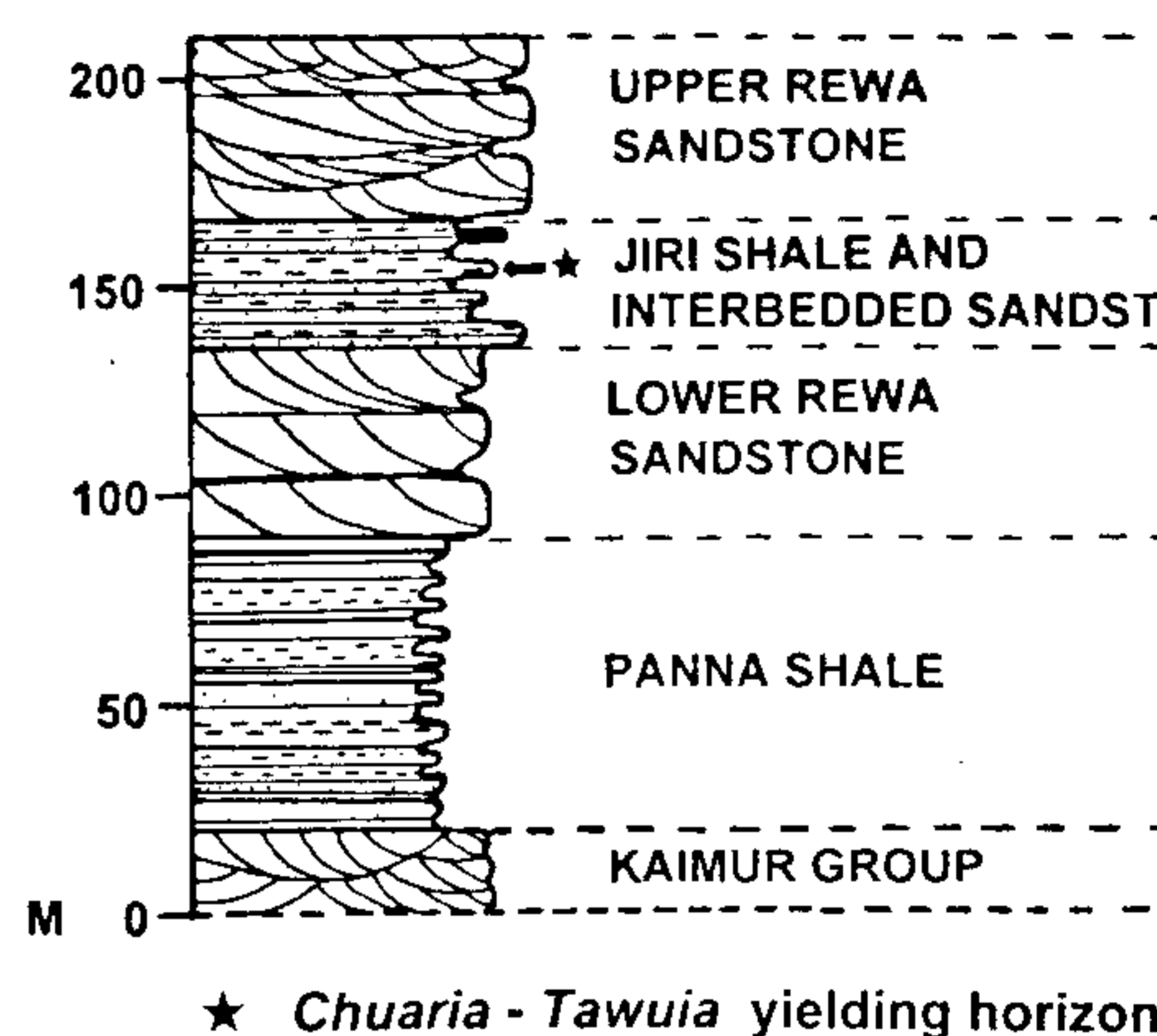


Figure 2. Lithological succession of the Rewa Group ex Sohagi village showing *Chuarina-Tawuia* yielding horizon after Sengupta²³.

and a few inter-spaced streaks of calcareous. These fine siliciclastic horizons are overlain by succession of medium to coarse grained ferruginous sandstone (Figure 2). The present horizon occurs below the sandstone and ferruginous siltstone (Figure 2).

All the specimens discussed here have been deposited in the museum of the Geology Department, University of Lucknow, Lucknow. Specimen numbers have been given in the figure description.

Systematic palaeontology

Group: Acritarcha Evitt, 1963 (ref. 26)

Genus: *Chuarina* Walcott, 1899 (ref. 27)

(Figures 3 c-f, h-j, l-n, p-r, t-v, x-z)

Type species: *Chuarina circularis* Walcott, 1899

Description: Compressed circular to ellipsoidal

Figure 3. a, Succession of the Rewa Group exposed on the road section. b, Buff to brown coloured Shale-Siltstone horizon yielding *Chuarina-Tawuia* fossils, hammer encircled for scale. (Scale for c = 10 mm, for d-z = 1.0 mm). c, (GDLU/97/VIN3) A cluster of *Chuarina* specimens scattered on the bedding plane with a few showing peripheral split. d, (GDLU/97/VIN4) Four different specimens of *C. circularis*, the lowermost partly preserved, the left one partly buried under the sediment layer and the top one showing wrinkles or concentric structure at the centre. e, (GDLU/97/VIN10) Four specimens on the bedding surface showing concentric wrinkles. The sample shows crack in the upper part. f, (GDLU/97/VIN6) One large and another small-sized specimen of *C. circularis*, both showing peripheral fold. g, (GDLU/97/VIN9) *Tawuia dalensis* showing folds and creases along the longer axis. h, (GDLU/97/VIN5) Deformed *C. circularis* tapering, however, concentric folds are well preserved. A dark spot is clearly seen in the middle of the compression. i, (GDLU/97/VIN13) Small sized *C. circularis* clustered in the upper part of the specimen with two overlapping large specimens in the left-central part. j, (GDLU/97/VIN14) Two well-developed compressed specimens of *C. circularis* showing peripheral foldings with larger specimen clearly showing a ring-like structure in its central part. k, (GDLU/97/VIN21) *T. dalensis* with slight tapering towards left. l, (GDLU/97/VIN20) Carbonaceous compressed *C. circularis* showing peripheral split in the lower part. m, (GDLU/97/VIN12) Dark carbonaceous disc of *C. circularis*. n, (GDLU/97/VIN15) Two specimens of *C. circularis*, the dark one carbonaceous while the one at the left showing typical 'V' shaped cracks/splits. o, (GDLU/97/VIN16) *T. dalensis* with minor elongated surfacial cracks. p, (GDLU/97/VIN5) Typical *C. circularis* with well-developed concentric annulations. q, (GDLU/97/VIN11) Partly preserved *C. circularis* showing peripheral concentric markings and 'V' split in the left margin. r, (GDLU/97/VIN17) Two *C. circularis* specimens showing concentric annulations. s, (GDLU/97/VIN5) *T. dalensis*. t, (GDLU/97/VIN7) Partly preserved *C. circularis* with well-preserved folds. u, (GDLU/97/VIN8) Partly preserved *C. circularis* with carbonaceous concentric markings. v, (GDLU/97/VIN18) Complete and another broken specimen of *C. circularis*. The smaller specimen shows angularity in folded sides. w, (GDLU/97/VIN1) 7 specimens of *C. circularis*. x, (GDLU/97/VIN15) 'Egg'-shaped specimen of *T. dalensis* without any internal feature or ornamentation. y, (GDLU/97/VIN11) 1 specimen of *C. circularis* with two spines emerging near the bottom of the photograph. z, (GDLU/97/VIN23) Three overlapping specimens of *C. circularis* from left to right.

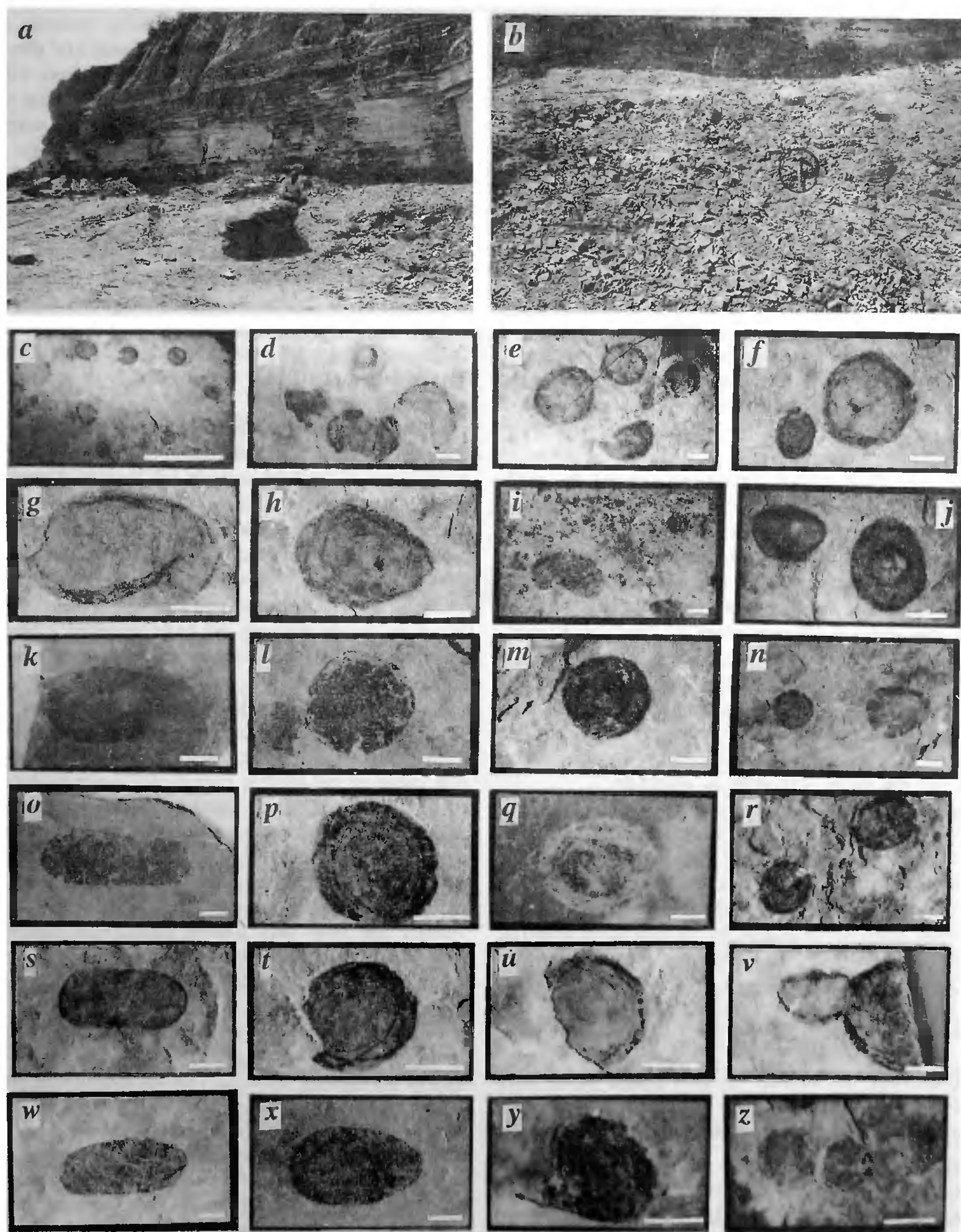


Figure 3a-z.

naceous discs, ranging in size from 1.0 mm to 3.7 mm, average being 2.0 mm. Concentric to irregular wrinkles on the surface particularly near the margins. Walls thick, psilate, opaque and without pores. Enveloping sheath absent. Marginal cracks and 'V'-shaped splits are occasionally present. A few specimens also show a cluster of concentric rings in the central part of the main compression.

Discussion: *Chuar* has been studied in detail²⁸⁻³⁶ by several workers. On the basis of its large size, *Chuar* was classed under acritarchs comparable to Leiosphaerids²⁸. However, Gussow³⁷ regarded these forms as spherical, planktonic organisms. Sun³³ described the form as spheroidal colonies of cellular filamentous cyanobacteria with spheroidal to elongate macroscopic bodies. He compared these forms to the living cyanobacteria *Nostoc*. However, this comparison does not hold good as *C. circularis* has a thick, sturdy sporopollenin-like organic wall³⁸ as reflected in the well-preserved forms. *Nostoc* on the other hand has a thin layer which is unlikely to be preserved.

SEM and TEM studies on *Chuar* reveal the wall to be a multilamellar structure³⁹. TEM study conducted by Jux⁴⁰ shows a 'fine network, trabecular ultrastructure of the wall'. The opaque character of the wall led to its earlier comparison with forms like *Fermoria* and *Protobolella*¹⁵ and various phosphatic fossils^{28,41}.

The size range of *Chuar* given by Ford and Breed²⁸ as 0.5 to 5.0 mm is not accepted by Vidal^{29,30}; his specimens from the Visingsö Formation were in the size range of 0.09 to 0.2 mm, going up to 3 mm. Vidal and Ford³¹ included specimens as small as 70 µm in *C. circularis*. The upper size limit is generally accepted at 5 mm but the lower size limit is uncertain.

Chuar is convincingly represented so far by only a single species, *C. circularis*. Although other species like *C. wimani*⁴², *C. globosa*⁴³, *C. fermorei*¹⁰ have been described, they lack convincing evidence to be placed under this genus⁶. Several workers^{28,31,44} have included *C. wimani* under *C. circularis*. *C. globosa* has a doubtful generic status as it has an enveloping sheath unlike the type species. *C. fermorei* lacks folds as opposed to the type species. Other species namely *C. annularis*⁴⁵ and *C. olavarriensis*⁴⁶ are placed under *C. circularis* as they have been established on the basis of preservational variations only. *C. minima*¹² is also placed along with *C. circularis* as it can only be identified in macerated specimens under the microscope (for exine studies).

Tawuia dalensis

Group: Acritarcha Evitt, 1963 (ref. 26)

Genus: *Tawuia* Hofmann (In Hofmann and Aitken, 1979) (ref. 5)

(Figures 3 g, k, o, s, w)

Type species: *Tawuia dalensis* Hofmann, 1979 (ref. 5)

Description: An elongated cylindrical form (tomaculate) with semicircular termini, compressed as carbonaceous film or as impressions if carbonaceous film absent. Surface ornamentation smooth, outline smooth, sides parallel to slightly tapering. Compressional fold preserved in one specimen. The length varies between 3.3 and 5.0 mm and width 1.6 and 2.2 mm. Aspect ratio varies between 1.6 and 2.94. Colour black carbonaceous to brown stained specimens depending on lithology.

Discussion: Hofmann and Aitken⁵ described *Tawuia dalensis*, from Little Dal Group, where it occurred alongside *Chuar circularis* Walcott, 1899. However, prior to the erection of this new genus, such fossils were reported²⁷ from the Belt Supergroup, Canada under the trace fossil genus *Helminthoidichnites*. Chapman¹⁵ recorded such fossils from the Vindhyan Supergroup of India as brachiopod genus *Protobolella*. Sahni⁴⁷ redesignated it to a new family Fermoriidae with undetermined affinity to *Fermoria*.

T. dalensis has since been recorded from Svalbard⁴⁸, China^{32,33,45}, India^{9,10,17} and Russia⁸. Hofmann⁶ and Sun³³ have given a detailed analysis of *Tawuia*. Duan³² discussed in detail the *Chuar-Tawuia* assemblage from eastern China but contended that *Tawuia* may only represent a ribbon-like body (flat) and not a compressed cylinder-like form. His observation was mainly based on the absence of twistings and foldings in the specimens. However, in our samples, we have recorded a specimen showing well-developed foldings and creases along the length of the form.

So far, *Tawuia* has been reported from the lower Vindhyan only^{9,10,13}. The present record suggests that the taxa continued in the upper Vindhyan as well. The size range of the present record of *Tawuia* is definitely towards its lower range (based on global data), although much larger specimens have been reported from Canada and China.

Chuar-Tawuia assemblage demarcates a unique co-existence in the Neoproterozoic. The distribution of *Tawuia* has been very limited globally in comparison to that of *Chuar* and therefore its present occurrence is significant in the light of its limited record from India.

Although carbonaceous compressions are known in India since Jones's report¹⁴, Mathur⁹ identified the form genera comprising *Chuar-Tawuia* assemblage for the first time from the Suket shales of the Semri Group, Vindhyan Supergroup in Rampura, Madhya Pradesh. This stratigraphic horizon lies within the ambit of the lower Vindhyan strata. However, the present assemblage records its occurrence from another younger level in the Rewa Group (Vindhyan Supergroup). The two localities are distantly apart by about 600–700 km, a fact which needs to be emphasized because of the wide extent of the basin. The circular carbonaceous discs

Table 1. Lithostratigraphic classification and geochronological ages of the Vindhyan Supergroup. Major classification after Auden⁵³. The radiometric dates are after Srivastava and Rajgopalan⁵⁴, Kreuzer *et al.*⁵⁵ and Crawford and Compston⁵⁶

PROTEROZOIC		AFTER 57 SASTRY & MOITRA		AGES IN Ma	THICKNESS	
ARCHAEAN	VENDIAN					
	RIPHEAN					
	VINDHYAN SUPERGROUP					
	UPPER	BHANDER GROUP	SHIKAODA S.ST. FM. SIRBU SHALE FM. BUNDI HILL S.ST. FM. LAKHERI L.ST. FM. GANURGARH SHALE FM.			
		REWA GROUP	GOVINDGARH S.ST. FM. — 710 +/- 120 ⁵⁴ JHIRI SHALE FM. — 700 +/- 120 ASAN S.ST. FM. — 690 +/- 125 PANNA SHALE FM. — 675 +/- 110	145-250M		
	KAIMUR GROUP	DHANDRAUL S.ST. FM. — 890 +/- 40 ⁵⁵ MANGESAR FM. BIJAIGARH SHALE FM. GHAGGAR S. ST. FM. SUSNAI BRECCIA FM. SASARAM FM.	50-350M			
	LOWER	SEMRI GROUP	ROHTAS SUBGROUP	BHAGWAR SHALE FM. ROHTASGARH LST. FM.	20-125M 200M	252M
			KHEINJUA SUBGROUP	RAMPUR FM. — 1080 +/- 40 ⁵⁵ SALKHAN LST. FM. KOLDAHA SHALE FM.	100-800M 90M 70-120M	1760M
			DEONAR FORMATION		870-1525M	753M
			MIRZAPUR SUBGROUP	KAJRAHAT LST. FM. ARANGI FM. DEOLAND FM.	135-145M 280-460M 45-200M	510M
BIJAWAR GROUP/ BUNDELKHAND GRANITIC COMPLEX/ CHOTANAGPUR GRANITIC COMPLEX			2400-2600 ⁵⁶			

comparable to *Chuar*, from the Rohtasgarh Formation of the Semri Group in the Katni area were found to occur along with *Grypania spiralis*²⁰. However, more detailed study of the biota is needed as Rai and Gautam⁴⁹ have also described several megascopic carbonaceous remains from Kaimur area, from a coeval stratigraphic horizon below the Kaimur Group. *Chuar* was recorded from the Deoban mountains of Lesser Himalaya⁵⁰. However, a closer examination of Tewari's⁵⁰ illustrations and specimens proved them to be either pseudo-fossils or simple spherical cavities.

Hofmann⁶ discussed the significance of the time range of *Chuar-Tawuia* assemblage with emphasis on the 700–1100 Ma span, while Sun and coworkers^{33,51} suggested a still precise range of 700–900 Ma for the biota. Zang⁵² on the basis of data from China suggested a much wider range for *Chuar* and *Tawuia*, i.e. from 1200 Ma to 600 Ma. The fact that *Tawuia* is invariably associated with *Chuar* but *Chuar* may not always occur with *Tawuia*, led Hofmann⁶ to establish a *Chuar-Tawuia* assemblage zone with its potential chronostratigraphical relevance. He also tried to interpret a possible link between the two taxa with their biological affinity closer to that of large-sized eukaryotic algae of planktic habit. Duan³² while discussing the affinity of *Chuar-Tawuia*, expressed his reservation about them being originally spherical and cylindrical bodies. He contended

that these may represent original discs and ribbon-like body plans, with closer affinity to leaf-like plants without wood fibres. However, he concluded that the association represents marine planktic multicellular algal plants which are mutually related. The significance of *Chuar-Tawuia* assemblage has been discussed at length by Sun³³. Based on improved techniques, Sun recorded filamentous cellular structures from *Chuar* and compared them with colonies of living blue-green alga, *Nostoc*. He considered *Tawuia* to have a very close taxonomic relationship with *Chuar* but put it separately as a distinct genus. Vidal and Ford³¹ considered *Chuar* to be an acritarch with the outer wall being psilate or chagrinate. They also considered that extremely small microscopic specimens (diameter 70 µm) might as well represent *Chuar*. An emphatic account of the *Chuar-Tawuia* association from Russia was given by Vidal and others⁸ with the observation on the assemblage's pre-Varanger age. Recently, Steiner³⁶ described the *Chuar-Tawuia* association from China and explained a possible biological affinity with recent cyanobacterial colonies of *Nostoc* balls. He also illustrated specimens attributed to *C. circularis* which were as small as 25 µm in diameter.

The *Chuar-Tawuia* assemblage of carbonaceous megafossils is recorded for the first time from the upper Vindhyan sequence of the Jhiri Shale Formation of the Rewa Group. This is the second such record from the

upper part of the Vindhyan Supergroup, the earlier being from the Suket shales of the lower Vindhyan succession.

The assemblage is a biostratigraphically crucial record as the association globally represents a time span from 1000 to 700 Ma, a pre-Vendian age.

This suggested age corroborates well with other geochronological dates of different horizons of the Vindhyan sequence.

The present find has opened up new vistas for search of such carbonaceous fossils in other younger horizons of the Vindhyan and coeval basins. A possibility of their occurrence in the Bhandar Group cannot be ruled out.

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