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MEGAFOSSILS FROM THE VINDHYAN BASIN, CENTRAL INDIA : AN OVERVIEW

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ABSTRACT

The Vindhyan Supergroup constitutes one of the largest Proterozoic basins of the world which attains a huge thickness of more than 5000m in central India. The rocks of the Vindhyan Supergroup are unmetamorphosed and more or less undeformed and the age of the Supergroup can be bracketed between ca. 1800 Ma to ca.650 (?) Ma. These rocks have been consistently searched for evidences of early life for more than a hundered years. Because of this, a large number of reports about the presence of megascopic life have been published from these rocks. These reports need scrutiny as many reports have described abiotic structures also as fossils. The paper reviews the megascopic fossils reported from the Vindhyan Supergroup between the year 2000 and 2015 and accepts most of the remarks made earlier by Sharma *et al.* (1992), Venkatachala *et al*. (1996) and Sharma (2003) on the reports published before the year 2000 with some additional comments. All noncarbonaceous fossils described as burrows, drag marks and trace fossils reported from both the lower and upper Vindhyans are rejected as fossils and considered as pseudofossils or nonfossils as these can be produced by many inorganic processes also, and the animals which could have produced these marks had not evolved during the deposition of the Vindhyan sediments. The reported Ediacaran fossils from the Upper Vindhyans are considered to be the weathering products of structures produced by inorganic processes and/or related to microbial mat structures. Thus, the presence of typical Ediacaran animal and plant fossils are not accepted in the Vindhyan rocks. Only carbonaceous megafossils occurring as compressions and impressions are considered as true fossils, out of which some are aggregates of organic matter. The carbonaceous fossils are dominated by *Chuaria – Tawuia* assemblage in both the lower and upper Vindhyans but in the eastern part of the Vindhyan Basin, the Bhander Group of the upper Vindhyans shows relatively more complicated forms and appear to represent more advanced morphologies in comparison with the Bhander Group of the western part. Only body fossil *Beltanelliformis minuta* recorded from the Maihar Sandstone of the Son Valley sector in the eastern part of the Vindhyan Basin has been accepted as true fossil. On the basis of mega-fossil records, the upper age of the Vindhyan Supergroup can be suggested as Pre-Ediacaran.

Keywords: Vindhyan Supergroup, mega-fossils, carbonaceous forms, central India, Proterozoic

INTRODUCTION

Understanding of Precambrian megascopic life is very important for resolving issues related to the evolution of early life on earth. But the identification of megascopic life as fossils in ancient rocks is difficult and often quite problematic. Moreover, all the Precambrian fossils need to be tested on three criteria before being considered as genuine/true fossils, i.e. biogenicity, syngenicity and age (Hofmann and Schopf, 1983). For this, it requires primarily two things; good preservation of fossil records and reliable age of the unit in which they are preserved. Syngenicity of the fossils is of course its basic requirement but biogenicity of the fossils can be inferred only by comparing their morphologies with available living analogues or when there is no way of producing such structures by any inorganic process. In majority of the cases, the geochemical data is also not available for any possible confirmation of the organic nature of the reported fossils. Thus, the onus of deciding biotic or abiotic nature of any fossil-like structure fully depends on the morphology of the fossils which in turn depends on the quality of preservation. With age, the quality of fossil record not only decreases but also becomes rarer. Structural deformation and effect of metamorphism on the fossil-bearing rocks also create problems as they destroy and/or modify the biogenic structures which in turn create difficulties in both search and study of such very ancient fossil records. Radiometric age data is very crucial which in most of the cases is not available. Thus, with these constraints it is not easy to identify areas where search for early fossil records with good preservation can be attempted. In India, the rocks of the Vindhyan Basin in central India are best suited for search and study of early life as the rocks are unmetamorphosed, more or less undeformed, cover a time span of more than one billion years from ca. 1800 Ma to ca. 650 (?) Ma and attain a huge thickness of more than 5000m. The quality of preservation of sedimentary structures in these rocks is excellent and the exposures are easily accessible. Because of these reasons, the Vindhyan rocks attracted the attention of scientists since more than a century when Jones, for the first time, recorded the preservation of circular discs in the Suket Shale of Neemuch district, Madhya Pradesh (M. P.) in 1909 which are now identified as *Chuaria circularis*, with a possible algal affinity. Since then, the concerted efforts have been made by many workers to search more evidences of megascopic life, and a large number of reports are now available on mega-fossils. But, many of them, when scrutinized, appear to have a doubtful biogenicity and in many cases abiotic structures have been described as fossils. It resulted in contamination of data on fossils with non-fossils and created a difficult situation for those workers who deal with the evolution of early life. Thus, it has become absolutely necessary to review all the published records and discard all such reports which have described abiotic structures and doubtful/dubiofossils from the Vindhyan rocks for extracting meaningful inferences. Sharma *et al.* (1992) were the first to evaluate all such reports dealing with metaphyte and metazoan fossils from the Precambrian sediments of India including the Vindhyan rocks. However, a more serious attempt was made in 1996 by Venketachala *et al.* who examined all available fossil records from the Vindhyan sediments published up to that time. They examined more than 50 mega-fossil records and identified 13 structures as true fossils and rest were placed under non-fossils and dubiofossils/pseudofossils. Sharma (2003) scrutinized additional reports dealing with 40 megascopic entities described from the Vindhyan sediments available between 1990 and 2000. In the present paper, an effort is made to re-assess comments of Venkatachala *et al.* (1996) and Sharma (2003). All their rejections as true fossils have been accepted and in addition some of their accepted true fossils have been re-evaluated. The present paper also evaluates all the reports published on the Vindhyan megafossils between 2001 and 2014. Only two categories are made in the present work for the described structures as fossils and non-fossils.

GEOLOGICAL SETTING OF THE VINDHYAN BASIN

The Vindhyan Basin occupies an area of 104000 sq. Km in central India stretching from Deri–on-Son (Bihar) in the east to Chittorgarh (Rajasthan) in the west (Fig. 1). The rocks of the Vindhyan Basin are referred to as the Vindhyan Supergroup exposed in the states of Bihar, Uttar Pradesh (U.P.), Madhya Pradesh (M.P.) and Rajasthan. The Vindhyan rocks are unmetamorphosed and more or less undeformed. In most of the areas the rocks are either horizontal or show very low dips. Good sections of the Vindhyan Supergroup are exposed by the Son and Chambal rivers which have cut through the Vindhyan succession in the eastern and western part of the Vindhyan Basin. The Vindhyan rocks unconformably overlie the Bundelkhand Granite (2492 ± 10 Ma; Mondal *et al.,* 2002) and Hindoli Group (1854 ± 7 Ma, Deb *et al.,* 2002) which includes Bijawar Group (see Malone *et al.*, 2008), and attains a thickness of more than 5000m. The basic lithology is represented by sandstones, siltstones, shales, porcellanites, limestones, dolostones and conglomerates. The Vindhyan Supergroup has been subdivided into four groups; in stratigraphic order these are the Semri Group, the Kaimur Group, the Rewa Group and the Bhander Group (Tables 1 & 2). The Semri Group is also referred to as the Lower Vindhyan and the remaining three groups viz., Kaimur, Rewa and Bhander are bracketed with the Upper Vindhyan. Each group has been further subdivided into different formations and members (Tables 1 & 2). Original lithostratigraphic subdivision of the Vindhyan Supergroup for the Son Valley section was given by Auden (1933) which is subsequently modified by Sastry and Moitra (1984). Since both the subdivisions are in use, hence both the classifications are given in the present work. Kumar (2012) has suggested that the Vindhyan Basin is made up of two sub-basins which show different stratigraphic successions with different thicknesses and can be referred to as the Son Valley sub-basin in the east and the Chambal Valley sub-basin in the west (Tables 1 & 2). It appears that the sub-basins have different geological history. The Upper Vindhyans of the Chambal Valley are best developed in the Kota–Bundi and adjoining areas, Rajasthan and in the Son Valley, they show excellent development in the Satna district, M.P.

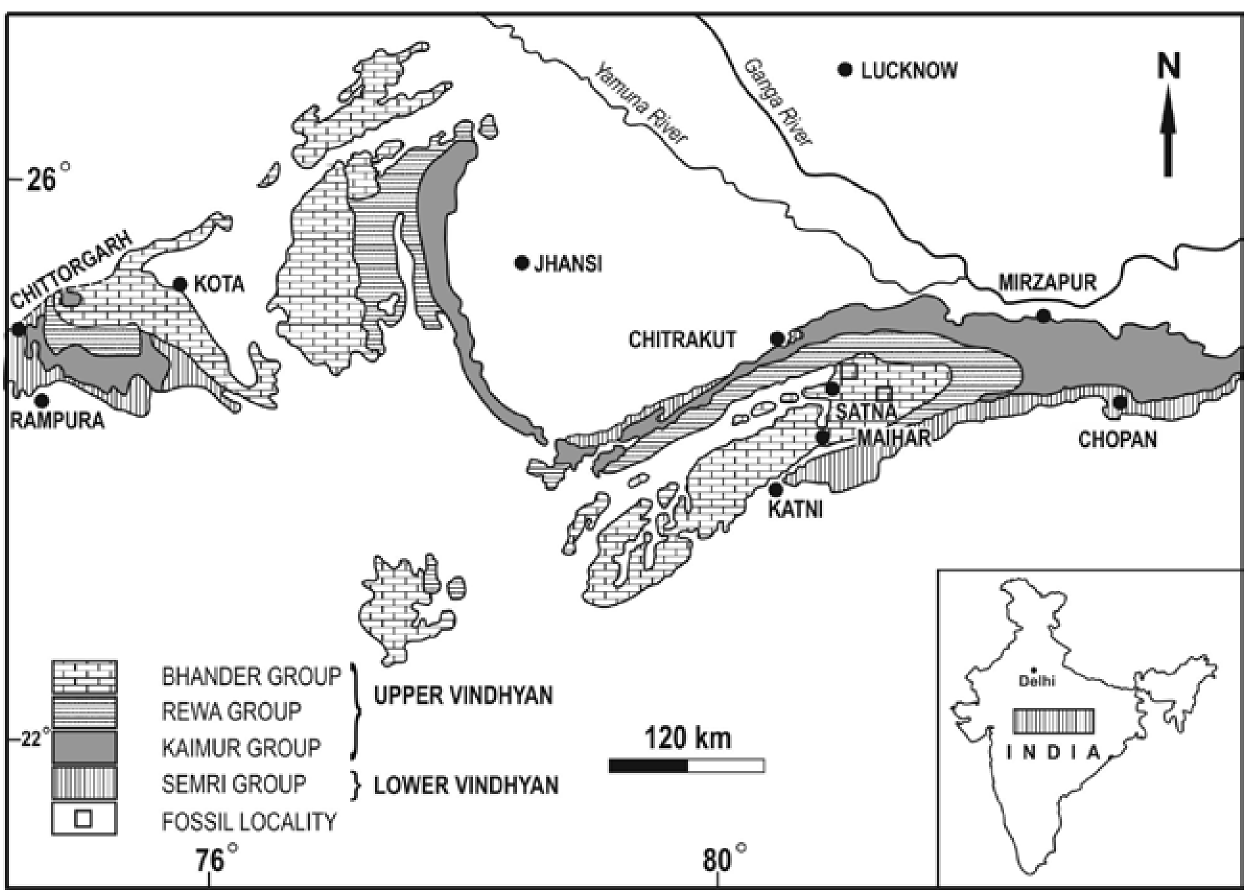

Fig. 1. Geological and location map of the Vindhyan Basin, central India (after Krishnan and Swaminath, 1959).

AGE OF THE VINDHHYAN BASIN

The age of the Vindhyan Supergroup has been debated since the beginning of the last century but it acquired an international dimension by the so called discoveries announced by Azmi (1998), Seilacher *et al.* (1998) and Kathal *et al.* (2000) as their inferences challenged the established concept of evolution of early life. All the three discoveries were subsequently challenged on the basis of critical scrutiny of their identification as fossils and also evaluated on the basis of recently acquired robust radiometric age and palaeomagnetic data. In earlier times, the age of the Vindhyan rocks was assigned from Palaeoproterozoic to Devonian (see Azmi *et al*., 2006, and references there in). For the Semri Group, a reasonably good radiometric age data is now available (Rasmussen *et al.*, 2002; Ray *et al.*, 2002, 2003; Sarangi *et al*., 2004) and thus, the age of the Semri Group is now more or less settled (Ray, 2006; Kumar and Sharma, 2012; Gopalan *et al*., 2013). It can be placed between 1800 and 1600 Ma but the end of the Vindhyan sedimentation is still debated as no reliable radiometric dates for the upper Vindhyans are available. On the basis of proxy records like carbonaceous and noncarbonaceous megafossils, microbial mat structures and stromatolites, the end of sedimentation in the Vindhyan Basin can be placed at ca. 600 Ma (Kumar, 2012; Kumar and Sharma, 2012) but recently there are many reports which suggest that the sedimentation ended in the Vindhyan Basin around at 1000 Ma based on palaeomagnetic data and zircon ages (Malone *et al*., 2006; Gregory *et al.,* 2006; Pradhan *et al.*, 2012; Turner *et al*., 2014; Basu and Bickford, 2015). Azmi *et al.* (2006) have given an excellent overview for the age of the Vindhyan sediments but with a biased approach to justify their own conclusion concerning the Cambrian age of the Rohtas Formation, the youngest formation of the Semri Group. In this effort, they accepted all such fossil reports which favoured their conclusions irrespective of whether they are biogenic or abiogenic. However, they have cited most of the relevant references which deal with the age of the Vindhyan sediments available up to that time and hence will not be discussed again.

The Vindhyan succession unconformably overlies the Bundelkhand granites and Hindoli rocks which have been dated as 2492 ± 10 Ma (Mondal *et al*., 2002) and 1854 ± 7 Ma (Deb *et al*., 2002) respectively. Therefore, the Vindhyan sediments should be younger than 1854 Ma. The Rohtas Formation has been dated as ca. 1600 Ma (Rasmussen *et al*., 2002; Ray *et al.,* 2002, 2003; Sarangi *et al*., 2004). A diamondiferous Majhgawan kimberlite pipe near Panna (M.P.) has intruded the Kaimur sandstone (Baghain Sandstone) which has been dated as 1073 ± 13 Ma (Gregory *et al.*, 2006) and whose diamonds have been recorded in the Rewa conglomerates of the Rewa Group. It means that the Kaimur sandstone should be older than 1073 Ma and the Rewa and Bhander groups represent sediments which should be younger than 1073 Ma. More recently, Tripathi and Singh (2015) have dated the black shales (Bijaigarh Shale) of the Kaimur Group by Re-Os method and suggested the depositional age as 1210 ± 52 Ma, which fixes the age of the Kaimur Group as ca. 1200 Ma. This restricts the age of the Rewa and Bhander Groups as younger than 1200 Ma.

No radiometric date is available for the Rewa Group, but recently the carbonates of the Bhander Group are dated by Pb-Pb method. By this method, Gopalan *et al.* (2013) have

Table 1: Lithostratigraphy of the Vindhyan Supergroup in the Son Valley.

	Modified after Auden (1933)			After Sastry and Moitra (1984)	
	GROUP	FORMATION	MEMBER	GROUP	FORMATION
UPPER VINDHYAN	Bhander	Maihar Sandstone Sirbu Shale Bhander Limestone Ganurgarh Shale		Bhander	Maihar Sandstone (Sikoda Sandstone) Sirbu Shale Bhander Limestone Ganurgarh Shale
	Rewa	Upper Rewa Sandstone Jhiri Shale Lower Rewa Sandstone Panna Shale		Rewa	Upper Rewa Sandstone (Govindgarh Sandstone) Jhiri Shale Lower Rewa Sandstone Panna Shale
	Kaimur	Dhandraul Quartzite Scarp Sandstone Bijaigarh Shale Upper Quartzite Susanai Breccia Silicified Shale Lower Quartzite		Kaimur	Dhandraul Quartzite Mangesar Formation Bijaigarh Shale Ghaghar Sandstone Susanai Breccia Sasaram Formation
			UNCONFORMITY		
LOWER VINDHYAN		Rohtas Formation		Rohtas Subgroup	Bhagwar Shale Rohtasgarh Limestone
	Semri	Kheinjua Formation	Glauconitic Sandstone Fawn Limestone Olive Shale	Kheinjua Subgroup	Rampur Formation Salkhan Limestone Koldaha Shale
		Porcellanite Formation	Porcellanites		Deonar Formation
		Basal Formation	Kajrahat Limestone Basal Conglomerate	Mirzapur Subgroup	Kajrahat Limestone Arangi Formation Deoland Formation
			UNCONFORMITY		
	Bijawar Group /Bundelkhand Granite	Schists and phyllite/Granites		Bijawar Group & Pre-Aravalli Group/ Bundelkhand Granite	

Table 2: Lithostratigraphic succession of the Vindhyan Supergroup in Kota-Chittorgarh area, Chambal Valley Section, Rajasthan (modified after Prasad, 1984).

	Group	Subgroup	Formation
UPPER VINDHYAN			Dholpura Shale
			Balwan Limestone
			Maihar Sandstone
	Bhander		Sirbu Shale
	Group		Bundi Hill Sandstone
			Somria Shale
			Lakheri Limestone
			Ganurgarh Shale
			Govindgarh Sandstone
	Rewa		Jhiri Shale
	Group		Indargarh Sandstone
			Panna Shale
			Akoda Mahadev Sandstone
	Kaimur		Badanpur Conglomerate
	Group		Chittorgarh Fort Sandstone
------------------------------ Unconformity ------------------------------			
LOWER VINDHYAN		Khorip Subgroup	Suket Shale
			Nimbahara Limestone
			Bari Shale
			Jiran Sandstone
		Lasrawan Subgroup	Binota Shale
			Kalmia Sanstone
	Semri		
	Group	Sand Subgroup	Palri Sahle
			Sawa Sandstone
			Bhagwanpura Limestone
		Satola Subgroup	Khairdeola Sandstone
			Khairmalia Andesite
--------------------------------- Unconformity ---------------------------------			
		Berach Granite/Bhilwara Group Metamorphics	Granite/Metamorphic Rocks

dated the Bhander Limestone, the Lakheri Limestone and the Balwan Limestone of the Bhander Group which have been given dates as 908 ± 72 Ma, 1073 ± 210 Ma and 866 ± 180 Ma respectively. The problem with the dates given by Gopalan *et al.* (2013) is that they have large error factor, especially for the Balwan and Lakheri Limestones and the only date of 908 ± 72 Ma for the Bhander Limestone can be of some help. If this date is accepted in the absence of more robust date, then the closure of the Vindhyan Basin in the Son Valley section can be speculated. There are two stratigraphic horizons overlying the Bhander Limestone in the Son Valley section of the eastern part of the Vindhyan Basin viz., the Sirbu Shale and the Upper Sandstone (Maihar Sandstone) (Table 1) with a total thickness of more than 400 m. If the age of the Bhander Limestone is accepted as ca. 900 Ma, then in the eastern part of the basin (Son Valley section) it is expected that time is needed for the deposition of 400m thick succession overlying the Bhander Limestone which could be up to several hundred million years. No Cambrian fossils have been reported from the Vindhyan rocks, so the Vindhyan sediments should definitely be the Precambrian rocks. The Ediacaran fossils described by De (2003, 2006) have not been accepted as fossils, as such, the age of the Bhander Limestone and the Sirbu Shale from where these fossils have been reported could not be assigned the Ediacaran age. Kumar and Pandey (2008) have described a microbial mat structure *Arumberia* and a body fossil *Beltanelliformis minuta* from the Maihar Sandstone, the youngest horizon of the Bhander Group in the Son Valley section. These suggest that the sedimentation should have ended near the Ediacaran period at ca. 630 Ma. It means that the Sirbu Shale and the Maihar Sandstone took ca. 300 million years for the deposition. It fits well with the available palaeontological data. If the thickness of the Bhander Group in the Son Valley section is compared with the thickness in the Chambal Valley section, then it is noted that in the Son Valley section it is ca. 500m, while in the Chambal Valley section it is ca. 1200m. This suggests that the thickness of the Bhander Group in the Son Valley is much less with respect to that in the Chambal Valley. Kumar (2012) has correlated the Bhander Limestone of the Son Valley with the Balwan Limestone of the Chambal Valley section on the basis of stromatolite assemblage of *Baicalia – Tungussia* (Fig. 2). Traditionally, the Bhander Limestone has been correlated with the Lakheri Limestone (see Bhattacharya, 1996; Sarkar *et al*., 1996; Chakraborty, 2004; De, 2006). This correlation is untenable because the carbon isotope signature of both the carbonate formations are different and the Bhander Limestone is characterised by the presence of stromatolites but these are absent in the Lakheri Limestone (Kumar *et al*., 2005). Kumar *et al*. (2005) and Kumar (2012) have correlated the Bhander Limestone with the Balwan Limestone. If this correlation is accepted, then it can be suggested that the succession in the eastern part of the basin is condensed on the basis of thickness in comparison with the western part. There is a possibility that the Maihar Sandstone of the Son Valley section is not even represented in the western part implying that the sedimentation ended first in the western part and sea regressed towards east. The sedimentation was continuing in the eastern part, i.e in the Maihar area of Son Valley section when it was already regressed from the Bundi area of Rajasthan. In this situation, there was a time gap between the closure of the Vindhyan Basin in the eastern and western parts. Now it is speculated that the Vindhyan sedimentation in the western part ended somewhere at 900 Ma on the basis of newly generated age data of the Bhander Limestone (Gopalan *et al*., 2013), but it continued in the eastern part as enough time was needed for the deposition of 400m thick succession overlying the Bhander Limestone. The Maihar Sandstone has yielded *Arumberia* and *Beltanelliformis minuta* (Kumar and Pandey, 2008) suggesting a relatively younger age in comparison to the Dholpura Shale of the Chambal section which has yielded only *Chuaria -Tawuia* assemblage (Srivastava, 2002). The presence of microbial mat structure *Arumberia* and *Beltanelliformis* in the Upper Sandstone (Maihar Sandstone) of the Bhander Group in the Son Valley section may indicate that its depositional age is nearer to the Ediacaran period. The underlying Sirbu Shale has yielded *Chuaria -Tawuia* assemblage with additional presence of more advanced carbonaceous fossils, such as *Chambalia minor*, cf. *Phascolites symmetricus*, *Bhanderia maiharensis* and cf. *Lanceoforma*; they also favour a younger age in comparison to the normal *Chuaria –Tawuia* assemblage of the Dholpura Shale of the Chambal Valley section as reported by Srivastava (2002). This implies that when sedimentation ended in the western part of the basin, it was continuing in the eastern part and it may have ended between 700 and 650 Ma ago or there is a possibility that it must have touched the beginning of the Ediacaran period at 635 Ma, but in no way did it go beyond the base of the Ediacaran period. Subsequently, sea regressed towards north through the Lesser Himalayan link of the Krol–Tal succession where sedimentation continued during Vendian–early Cambrian Period as envisaged by Singh and Rai (1983). Thus, the age bracket from 1800 Ma to 650 Ma can be envisaged for the Vindhyan Basin.

MEGAFOSSILS REPORTED BEFORE THE YEAR 2000

The megafossils have been abundantly reported from the Vindhyan sediments and reviewed earliar by Venkatachala *et al.* (1996) and Sharma (2003) in detail. Venkatachala *et al.* (1996) have given a comprehensive account of all the megafossils published up to that time. They reviewed about 50 fossil reports and accepted only 13 entities as fossils and rejected all other reports. All their rejections have been accepted in the present work but their acceptance of 13 reports as fossils have been again reviewed. Besides, all reports of trace fossils have been rejected as fossils with a notion that animals which could have created traces and burrows were absent at the time of Vindhyan sedimentation. The animals could not have evolved during Vindhyan times and hence, there is no possibility of the preservation of traces and burrows in the Vindhyan rocks. Thus, reports of burrows and trace fossils described by Vredenburg (1908), Misra and Awasthi (1962), Verma and Prasad (1968), Sisodia and Jain (1984) and Chakrabarti (1990) have been put under the category of non-fossils. There are many inorganic processes which can produce similar structures. The report of *Chuaria* and *Tawuia* by Maithy and Babu (1988) appears to be secondary encrustations not made up of carbonaceous matter. *Rampuraea vindhyanensis* reported by Maithy and Shukla (1984) also appears to be a non-fossil as the morphology looks like a mode of splitting of bed plane and is also noncarbonaceous. Thus, only such reports which deal with structures made up of carbonaceous matter including *Katnia singhii, Tyrasotaenia, Chuaria*, and *Tawuia* represent true fossils. It is suggested that out of these 13 fossil reports accepted by Venkatachala *et al.* (1996), only five reports should be accepted as true fossils as all noncarbonaceous morphologies and all reports dealing with trails, drag marks and burrows should be rejected as fossils (see Table 3). However, the circular structure reported by Beer (1919) from the Rohtas Formation and described as trace fossil *Spiroichnus beerii* by Mathur (1983) appears to be a pseudomorph after *Grypania*.

Sharma (2003) has reviewed 40 fossils reported between the years 1990 and 2000 (Table 4). He subdivided these fossil reports into four groups as carbonaceous compressions, metazoan fossils, trace fossils and small shelly fossils. He has considered 12 carbonaceous fossils and out of which he accepted only eight as true fossils, three as organic matter aggregate and one fossil described by Maithy (1991) as *Krishnania multistriata* as pseudofossil. Remaining 28 fossils are put under the categories of either pseudofossil or dubiofossil. In the present paper, both these categories are grouped as non-fossils. All the conclusions of Sharma (2003) are accepted (see Table 4).

MEGAFOSSILS REPORTED AFTER THE YEAR 2000

In the present review, the papers published after the year 2000 are considered for detailed analysis. Only twelve papers have been published between 2000 and 2015 on the megafossils.

Kumar (2001) published a detailed report on the fossils recorded from the Suket Shale of the Chambal Valley section in the western part of the Vindhyan Basin. The Suket Shale has been traditionally included within the Semri Group and as such its age should be ca. 1600 Ma. But it shows a conformable contact with the overlying Kaimur sandstone and thus can also be included in the Kaimur Group. This suggestion can be accepted because in the eastern part of the Vindhyan Basin (Son Valley section) there is a well-marked unconformity between the Semri Group and the Kaimur Group (Kumar and Sharma, 2012). So if the Suket Shale is accepted as a part of the Kaimur Group then the age of the Suket Shale should be linked to the age of the Kaimur Group which is definitely older than ca. 1073 Ma because a diamondiferous kimberlite pipe has intruded the Kaimur Sandstone in the Panna area (M.P.) which has been dated as 1073 Ma by Gregory *et al.* (2006). Recently, Tripathy and Singh (2015) have given a Re-Os depositional age of the Bijaigarh Shale of the Kaimur Group as 1210 ± 53 Ma. This data and the age of the Majhgawan pipe (1073 ± 13 Ma) which has intruded the Kaimur Sandstone suggests that the Suket Shale should be older than ca 1200 Ma. From the Suket Shale, nine megafossils have been described by Kumar (2001). More than hundred years back, Jones (1909) had reported from the same shale the circular discs now identified as *Chuaria circularis*. Kumar (2001) has reported eight carbonaceous fossils as *Chuaria circularis, Chuaria vindhyanensis, Tawuia dalensis, Tawuia indica, Suketia rampuraensis, Tilsoia khoripensis, Chambalia minor* and *Beltina danai* and a noncarbonaceous fossil referred to as Form A. The Form A is a pseudomorph of *Chuaria circularis.* All reported fossils have been accepted as true fossils. The *Beltina danai* in the assemblage has been considered as a fragment of some unknown fossil. Rest of the forms are linked to algal forms.

Srivastava (2002) described *Chuaria – Tawuia* assemblage from the Dholpura Shale, the youngest horizon of the Bhander Group in the Chambal Valley section, Rajasthan. This assemblage is made up of carbonaceous matter and is acceptable as true fossils.

Kumar and Srivastava (2003) have reported seven species belonging to six genera and three forms are informally described from the Bhander Group of the Son Valley section in the eastern part of the Vindhyan Basin. All the reported forms are carbonaceous in nature and represent true fossils. These forms are *Chuaria circularis*, *Chuaria dulniensis, Tawuia dalensis, Chambalia minor, Phascolites symmetricus, Bhanderia maiharensis,* cf. *Lanceoforma* sp. and three are informally described as Form A, Form B and Form C. At present, it is not possible to suggest taxonomic affinity of this assemblage but its close relationship with various types of algae can be envisaged.

Srivastava (2004) reported carbonaceous compressions from the Panna Shale of the Rewa Group exposed in Drummondganj area, Son Valley section. She has discussed the size variation

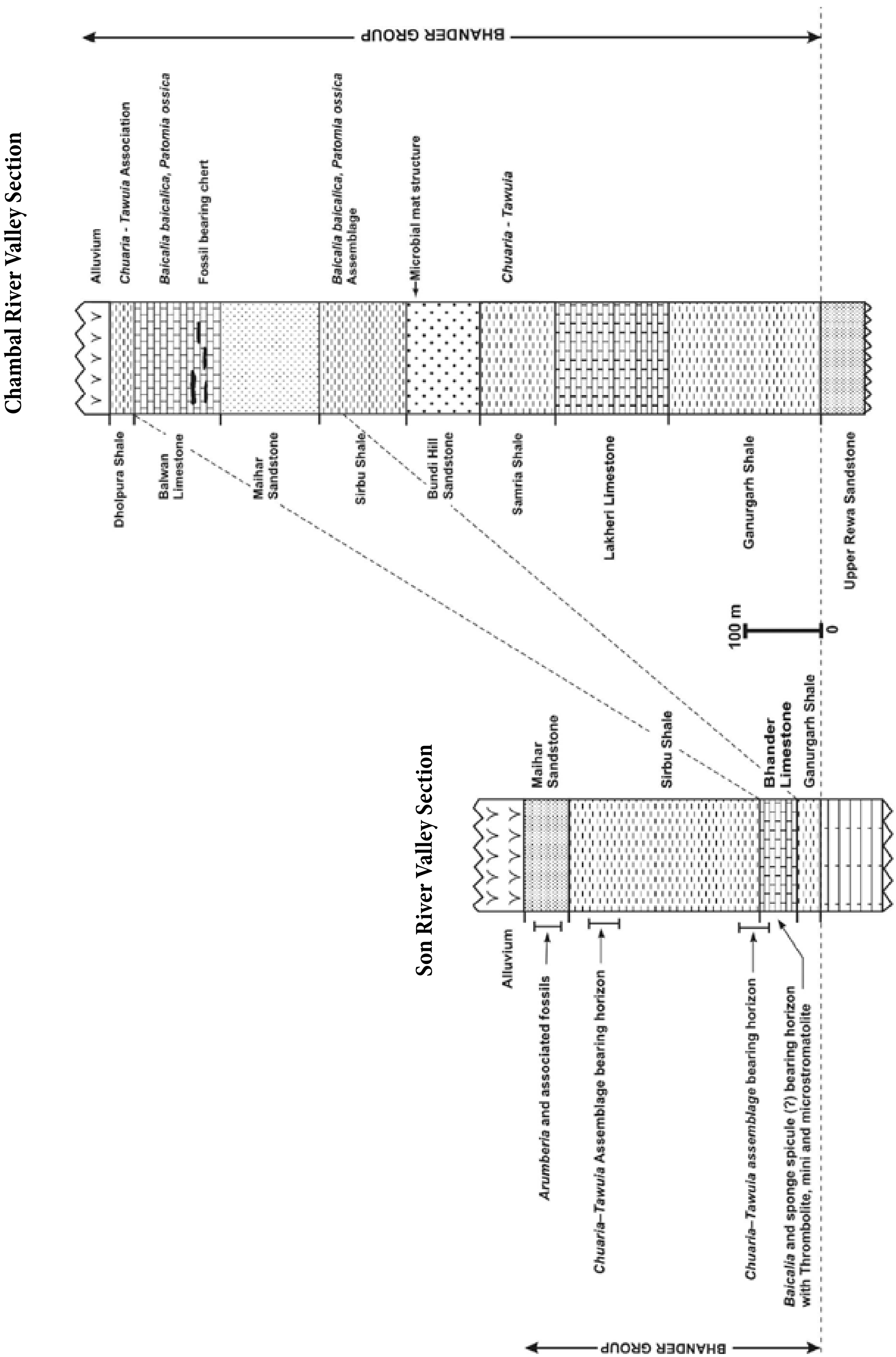

Fig. 2: Correlation of the Bhander Limestone with the Balwan Limestone (after Kumar, 2012).

Table 3: A tabulated scheme of macrofossil distribution in the Vindhyan Supergroup reported prior to 1996. (after Venkatachala *et al*., 1996).

S. No.	Group	Reference	Evidence	Remarks	Present Work
1.	**Bhander**	Mathur and Verma, 1983	*Bhanrerichnus damohonsis*	Dubio fossil	Non-fossil
2.		Chakrabarti, 1990	Drag markings, Lonzenge shaped bodies, mud volcanoes like structures	Dubio fossil	Non-fossil
3.		Chakrabarti, 1990	Burrows	Fossil	Non-fossil
4.		Vrendenburg, 1908	Trace fossil	Fossil	Non-fossil
5.		Verma and Prasad, 1968	Trace fossils	Fossil	Non-fossil
6.		Sarkar, 1974	Burrows	Non-fossils	Non-fossil
7.		Maithy, 1990	*Cyclomedusa davidi*	Non-fossil	Non-fossil
8.		Maithy and Gupta, 1981	*Turbocyathus vindhyanensis*	Non-fossil	Non-fossil
9.		Das *et al*., 1987	Trace fossil	No comments	Non-fossil
10.		Dubey, 1982	Trilobite and Eurypterid forms	No comments	Non-fossil
11.	**Rewa**	Mathur, 1982	*Asteriradiatus karauliensis*	No comments	Non-fossil
12.	**Kaimur**	Maithy, 1990	Vendotaenid remains	Non-fossil	Non-fossil
13.		Maithy and Babu, 1988	Ichnogenus type “A” and “B”	Non-fossil	Non-fossil
14.		Shukla and Sharma, 1990	Trace fossil	Fossil	Non-fossil
15.		La Touche, 1902	*Chordoichnus latouchei*	No comments	Non-fossil
16.	**Semri**	Prakash, 1966	Brachiopod shell	Dubio fossil	Non-fossil
17.		Rode, 1946	*Hyolithes rohitaswei*	Dubio fossil	Non-fossil
18.		Sisodia, 1982	Jelly fish	Dubio fossil	Non-fossil
19.		Misra, 1946	*Misracyathus vindhyanus*	Dubio fossil	Non-fossil
20.		Shukla and Sharma, 1990	cf. *Podolithus* sp.	Dubio fossil	Non-fossil
21.		Mathur, 1982	*Sojiwashman basuhariensis*	Dubio fossil	Non-fossil
22.		Misra and Awasthi, 1962	Burrow	Fossil	Non-fossil
23.		Sisodiya and Jain, 1984	Burrow	Fossil	Non-fossil
24.		Maithy and Babu, 1988	*Chuaria, Tawuia*	Fossil	Non-fossil
25.		Maithy, 1969	*Tasmanites*	Fossil	Fossil
26.		Tandon and Kumar, 1977	*Katnia singhi*	Fossil	Fossil
27.		Maithy and Shukla, 1984	*Ramapuraea vindhyanensis*	Fossil	Non-fossil
28.		Beer, 1919 (Mathur, 1983)	*Spiroichnus beerii*	Fossil	Fossil
29.		Maithy and Shukla, 1984	*Tawuia dalensis*	Fossil	Fossil
30.		Shukla and Sharma, 1990	*Tyrasotaenia, Tawuia*	Fossil	Fossil
31.		Maithy and Gupta, 1981	*Ajaicicyathus tandoni*	Non-fossil	Non-fossil
32.		Maithy and Shukla, 1984	*Allatheca*	Non-fossil	Non-fossil
33.		Maithy et al., 1986	Annelid traces	Non-fossil	Non-fossil
34.		Maithy et al., 1990	*Beltanelloides*	Non-fossil	Non-fossil
35.		Sarkar, 1974	Burrows	Non-fossil	Non-fossil
36.		Maithy and Shukla, 1984	*Coleolella billingsi*	Non-fossil	Non-fossil
37.		Maithy, 1990	Frondoid form	Non-fossil	Non-fossil
38.		Maithy, 1990	Vendotaenid remains	Non-fossil	Non-fossil
39.		Maithy, 1990	Krishnanid form	Non-fossil	Non-fossil
40.		Maithy and Babu, 1988	*Longfengsahnia chopanensis*	Non-fossil	Non-fossil
41.		Maithy and Babu, 1988	*Longfengsahnia stipitata*	Non-fossil	Non-fossil
42.		Kumar, 1978	*Muniaichnus*	Non-fossil	Non-fossil
43.		Singh and Chandra, 1987	*Rohtasia tandonii*	Non-fossil	Non-fossil
44.		Maithy and Babu, 1988	*Sekwia excentrica*	Non-fossil	Non-fossil
45.		Maithy et al., 1986	*Sekwia excentrica*	Non-fossil	Non-fossil
46.		Saxena, 1980	*Skolithos*	Non-fossil	Non-fossil
47.		Maithy and Gupta, 1981	*Tubocyathus vindhyanensis*	Non-fossil	Non-fossil
48.		Maithy and Babu, 1988	*Vendotaenia*	Non-fossil	Non-fossil

Table 4: Present status of carbonaceous remains, metazoan fossils, trace fossils and small shelly fossils reported between 1990-2000 A.D. from different stratigraphic levels of the Vindhyan Supergroup of India (after Sharma, 2003).

S. No.	Reported form	Reference	Status	Present Work
Carbonaceous compression				
1	*Chuaria circularis*	Kumar, 1995	True fossils	Fossil
2	*Chuaria circularis*	Kumar and Srivastava, 1997	True fossils	Fossil
3	*Chuaria circularis*	Rai *et al*., 1997	True fossils	Fossil
4	*Chuaria circularis*	Rai and Gautam, 1998	Organic matter aggregate	Non-fossil
5	*Chuaria gigantia*	Rai and Gautam, 1998	Organic matter aggregate	Non-fossil
6	*Chuaria melanocentricus*	Rai and Gautam, 1998	Organic matter aggregate	Non-fossil
7	*Grypania spiralis*	Kumar, 1995	True fossils	Fossil
8	*Grypania spiralis*	Rai and Gautam, 1998	True fossils	Fossil
9	*Krishnania multistriata*	Maithy, 1991	Pseudofossils	Non-fossil
10	*Phyllonia bistaria*	Rai and Gautam, 1998	True fossils	Fossil
11	*Tawuia dalensis*	Kumar and Srivastava, 1997	True fossils	Fossil
12	*Tawuia dalensis*	Rai *et al*., 1997	True fossils	Fossil
Metazoan Fossils				
13	*Beltanelliformis brunsae*	Maithy *et al*., 1992	Pseudofossils	Non-fossil
14	*Cyclomedusa davidi*	Maithy *et al*., 1992	Pseudofossils	Non-fossil
15	*Medusinites asteroids*	Maithy *et al*., 1992	Pseudofossils	Non-fossil
16	*Spriggina*	Kathal, *et al*., 2000	Dubiofossil	Non-fossil
17	Sponge specule	Kumar, 1999	Dubiofossil	Non-fossil
Trace fossils				
18	*Chondrites* sp.	Rastogi and Srivastava, 1992	Pseudofossils	Non-fossil
19	*Cochlichnus anguineus*	Kulkarni and Borkar, 1996a	Pseudofossils	Non-fossil
20	*Hormosiroidea*	Rastogi and Srivastava, 1992	Pseudofossils	Non-fossil
21	*Monomorphichnus* sp.	Rastogi and Srivastava, 1992	Pseudofossils	Non-fossil
22	*Ormathichnus moniliformis*	Rastogi and Srivastava, 1992	Pseudofossils	Non-fossil
23	*Palaeophycus* sp	Rastogi and Srivastava, 1992	Pseudofossils	Non-fossil
24	*Pelecypodichnus* sp.	Rastogi and Srivastava, 1992	Pseudofossils	Non-fossil
25	*Planolites* sp.	Rastogi and Srivastava, 1992	Pseudofossils	Non-fossil
26	*Rhizocorallium* sp.	Rastogi and Srivastava, 1992	Pseudofossils	Non-fossil
27	*Skolithos linearis*	Kulkarni and Borkar, 1996a	Dubiofossil	Non-fossil
28	Trace fossil	Sarkar *et al*., 1996	Pseudofossils	Non-fossil
29	Trace fossil	Seilacher *et al.,* 1998	Pseudofossils	Non-fossil
Small Shelly Fossils				
30	Acrotretid brachiopod*	Azmi, 1998a	Pseudofossils	Non-fossil
31	*Camenella* sp. A.	Azmi, 1998a	Pseudofossils	Non-fossil
32	*Camenella* sp. B.	Azmi, 1998a	Pseudofossils	Non-fossil
33	*Camenella* sp. C.	Azmi, 1998a	Pseudofossils	Non-fossil
34	*Codonoconus* sp.	Azmi, 1998a	Dubiofossil	Non-fossil
35	*Halkieria* sp.	Azmi, 1998a	Pseudofossils	Non-fossil
36	*Lapworthella* sp.	Azmi, 1998a	Pseudofossils	Non-fossil
37	Obolellid brachiopod*	Azmi, 1998a	Pseudofossils	Non-fossil
38	*Olivooides multisulcatus*	Azmi, 1998a	Pseudofossils	Non-fossil
39	*Spirellus shankari*	Azmi, 1998a	Dubiofossil	Non-fossil
40	*Talliella himalayaica*	Azmi, 1998a	Dubiofossil	Non-fossil

of *Chuaria* and tried to link it with the evolution of life from micro to mega forms. She has also reported the occurrence of *Tilsoia khoripensis* and *Tawuia dalensis*. All forms are accepted as true fossils.

De (2003) reported two forms from the Bhander Limestone exposed in the Satna district which he has compared with *Ediacaria* and *Hiemalora.* Subsequently, De (2006) described nine coelenterate genera *Tribachidium, Eoporita, Kaisalia, Cyclomedusa, Ediacaria, Nimbia, Paliella, Medusinites* and *Hiemalora*, one arthropod genus *Spriggina* and a few unnamed forms belonging to sponge and coelenterate from the Bhander Limestone and Sirbu Shale formations of the Son Valley section. The main problem with this report is that the preservation of fossils is so poor that not much could be deciphered from the photographs. Quality of the photographs is also very bad and fails to show the diagnostic characters of the described forms. The identification of the genera is made by making sketches and drawings which are very subjective and speculative. As such, comments and evaluation on each identification is meaningless. They are probably weathering features showing superficial but poor resemblance with certain known forms. None of the reported fossils are accepted as biogenic and can be put under non-fossil category. In the light of this, the reports of De (2003, 2006) should be neglected till well-preserved Ediacaran forms are discovered.

Sharma (2006) has described carbonaceous films from the Olive Shale (Koldaha Shale) of the Kheinjua Formation belonging to the Semri Group, Son Valley section, and identified them as multicellular/thalloid macro-algae. These films are grouped as *Changchengia stipitata, Tuanshanzia lanceolata, T. platyphylla, Leiosphaeridia* sp. and *Eopalmaria prinstina* and considered to be the oldest megascopic remains from India. Their age may be ca. 1650 Ma. These are fossils of uncertain affinity.

From the Chorhat Sandstone (Glauconitic Sandstone), Semri Group, Rewa area (M.P.) which has been dated by Rasmussen *et al.* (2002) by U/Pb zircon age as 1.6 Ga, Srivastava and Bali (2006) have described compressed carbonaceous remains as *Chuaria - Tawuia* assemblage. Only *Chuaria* can be identified with any degree of confidence. There are also some filamentous forms but no other form including *Tawuia* is identifiable.

Sharma and Shukla (2009a) have described the occurrence of *Grypania circularis* from the Rohtas Formation exposed in the Rohtas district of Bihar from a shale slab. It is accepted as a fossil.

Table 5: List of megafossils reported between 2000 and 2014.

S. No	Fossils	Stratigraphic Horizon	Reference	Remark	Category
1.	*Chuaria circularis*	Suket Shale (Chambal Valley)	Kumar (2001)	Carbonaceous	Fossil
2.	*Chuaria vindhyanensis*			Carbonaceous	Fossil
3.	*Tawuia dalensis*			Carbonaceous	Fossil
4.	*Tawuia indica*			Carbonaceous	Fossil
5.	*Suketea rampuraensis*			Carbonaceous	Fossil
6.	*Tilsoia khoripensis*			Carbonaceous	Fossil
7.	*Chambalia minor*			Carbonaceous	Fossil
8.	*Beltina danai*			Carbonaceous	Fossil
9.	Form A			Mould of *Chuaria circularis*	Fossil
10.	*Chuaria*	Dholpura Shale (Chambal Valley)	Srivastava (2002)	Carbonaceous	Fossil
11.	*Tawuia*			Carbonaceous	Fossil
12.	cf. *Phascolites symmetricus*	Sirbu Shale (Son Valley)	Kumar and Srivastava (2003)	Carbonaceous	Fossil
13.	cf. *Lanceoforma* sp.			Carbonaceous	Fossil
14.	Form C			Carbonaceous	Fossil
15.	*Chuaria circularis*	Sirbu Shale & Bhander Limestone (Son Valley)		Carbonaceous	Fossil
16.	*Tawuia dalensis*			Carbonaceous	Fossil
17.	*Chuaria dulniensis*	Bhander Limestone (Son Valley)		Carbonaceous	Fossil
18.	*Chambalia minor*			Carbonaceous	Fossil
19.	*Bhandaria maiharensis*			Carbonaceous	Fossil
20.	Form A			Carbonaceous	Fossil
21.	Form B			Carbonaceous	Fossil
22.	*Chuaria*	Panna Shale (Son Valley)	Srivastava (2004)	Carbonaceous	Fossil
23.	*Tilsoia khoripensis*			Carbonaceous	Fossil
24.	*Changchengia stipitata*	Koldaha Shale (Olive Shale) (Son Valley)	Sharma (2006)	Carbonaceous	Fossil
25.	*Tuanshanzia platyphylla*			Carbonaceous	Fossil
26.	*Tuanshanzia lanceolata*			Carbonaceous	Fossil
27.	*Leiosphaeridia* sp.			Carbonaceous	Fossil
28.	*Eopalmaria prinstina*			Carbonaceous	Fossil
29.	*Chuaria*	Chorhat Sandstone	Srivastava and Bali (2006)	Carbonaceous	Fossil
30.	*Tawuia*			Carbonaceous	Identification doubtful
31.	*Tribachidium*	Sirbu Shale (Son Valley)	De (2003, 2006)	Weathering pattern	Non-fossil
32.	*Eoporite*			Weathering pattern	Non-fossil
33.	*Nimbia*			Weathering pattern	Non-fossil
34.	*Spriggina*			Weathering pattern	Non-fossil
35.	Probable sponge			Weathering pattern	Non-fossil
36.	Probable coelenterate			Weathering pattern	Non-fossil
37.	*Ediacaria*	Sirbu Shale and Bhander Limestone (Son Valley)		Weathering pattern	Non-fossil
38.	*Hiemalora*			Weathering pattern	Non-fossil
39.	*Kaisalia*	Bhander Limestone (Son Valley)		Weathering pattern	Non-fossil
40.	*Cyclomedusa*			Weathering pattern	Non-fossil
41.	*Paliella*			Weathering pattern	Non-fossil
42.	*Medusinites*			Weathering pattern	Non-fossil

43.	*Beltanelliformis minuta*	Maihar Sandstone (Son Valley)	Kumar and Pandey (2008)	Body fossil	Fossil
44.	*Grypania spiralis*	Rohtas Formation (Son Valley)	Sharma and Shukla (2009a)	Carbonaceous	Fossil
45.	*Katnia singhii*		Sharma and Shukla (2009b)	Carbonaceous	Fossil
46.	*Grypania spiralis*	Rohtas Formation (Son Valley)		Carbonaceous	Fossil
47.	*Proterotainia montana*			Carbonaceous	Fossil
48.	*Proterotainia katniensis*			Carbonaceous	Fossil
49.	*Spiroichnus beerii*			Pseudomorph	Fossil
50.	*Chuaria* sp.			Carbonaceous	Fossil
51.	Circular discs			Impression	Non-fossil
52.	Form A	Rohtas Formation (Son Valley)	Srivastava (2012)	Reported by Srivastava (2011) as discs with segmented structure	Fossil
53.	Form B	Rohtas Formation (Son Valley)		Reported by Srivastava (2011) as dichotomous branching structure in association of *Grypania*. Impression on limestone.	Non-fossil
54.	Form C	Rohtas Formation (Son Valley)		Carbonaceous	Fossil
55.	Form D	Sirbu Shale Locality not known		Poorly preserved carbonaceous matter	Non-fossil
56.	Form E	Sirbu Shale (Son Valley)		*Tawuia* like carbonaceous vesicle	Fossil
57.	Form F	Dholpura Shale (Chambal Valley)		Subrecent contaminant	Non-fossil
58.	Form G	Sirbu Shale Locality not known		Association of organic matter	Non-fossil
59.	Form H	Dholpura Shale (Chambal Valley)		*Chuaria* like carbonaceous form	Fossil
60.	Form I	Samria Shale (Chambal Valley)		*Tawuia* like carbonaceous aggregate	Fossil
61.	Form J	Samria Shale (Chambal Valley)		Aggregate of carbonaceous matter	Non-fossil

Sharma and Shukla (2009b) have reported a well-preserved assemblage of fossils which are occurring as straight, circular, sinuously coiled and helical megascopic morphologies from the Rohtas Formation of the Semri Group from the Katni district, M.P. The assemblage is made up of *Katnia singhii, Grypania spiralis, Proterotainia montana, Proterotainia katniensis, Spiroichnus beerii* and *Chuaria* sp. All are carbonaceous except *Spiroichnus beerii* which appears as pseudomorph after *Grypania circularis*. The assemblage is considered as true fossils.

Singh *et al*. (2009) announced the discovery of carbonaceous remains from the Neoproterozoic shales of the Bhander Limestone and the Sirbu Shale of the Son Valley Section, M.P., although the carbonaceous fossils were already reported earlier by Kumar and Srivastava (1997, 2003) from the same horizons and from the same area (Maihar area, M.P.). They have described eighteen taxa, out of which two new genera were erected. The fossils belong to both planktonic and benthic meso-megscopic multicellular metaphites. These are of varied shapes viz., leaf-like thalloid films, palmate, straight to curved with or without hold-fast. Some filamentous forms are dichotomously branched and compactly entangled. The problem with this report is that the fossil material is very poorly preserved and the photographs are of very bad quality, most of them being out of focus. This makes the report less meaningful and individual identifications useless. Hence, individual identification is not discussed in the present review but broadly this can be said that the carbonaceous assemblage is made up of *Chuaria, Tawuia* and filamentous and leaf-like thalloid forms. The list of the described forms is given in Table 5. This assemblage shows much similarity with the assemblage described by Kumar and Srivastava (1997, 2003) from the Bhander Limestone and Sirbu Shale. They have reported *Phascolites*, cf. *Lanceoforma, Chambalia, Chuaria, Tawuia*, *Bhanderia* and three informal filamentous forms.

Srivastava (2011) has reported problematic fossils from the Vindhyan sediments. She described sixteen such forms, out of which ten forms are megascopic and the rest are microfossils. The same forms have been described by her again in 2012, in which she has given them informal designation as Form A, Form B … Form J (Srivastava, 2012) (Table 5). Most of these forms are based on single specimens and perhaps this was the reason for her to describe them informally. Out of these ten forms, two forms, reported as megascopic branched filaments with attached vesicles from the Dholpura Shale, Rajasthan, and as a dichotomously branching form associated with *Grypania*-like object from the Rohtas Formation, are not accepted as fossils; the former appear to be a sub-recent contaminant and the latter looks like an abiotic structure. The remaining seven forms can be grouped as fossils with unusual morphologies whose affinity could not be established. There is a possibility that some of the morphologies may be the product of taphonomy. Srivastava (2012) has published seven photographs which she had already published in 2011 (see Srivastava, 2011) and has reported 11 forms. Out of these, Form K is a microscopic form and Form F appears to be a contaminant. The Form B appears to be a structure which could have been produced by inorganic process. She has also published six photographs of the Ediacaran fossils from the Bundi Hill Sandstone (Bhander Group), Rajasthan which may have some superficial resemblance with some known Ediacaran forms but these structures could have also been produced by inorganic processes or may represent the microbial mat-related discs, and hence, should be neglected till better preserved samples are recovered. The remarks for each form have been given in the Table 5.

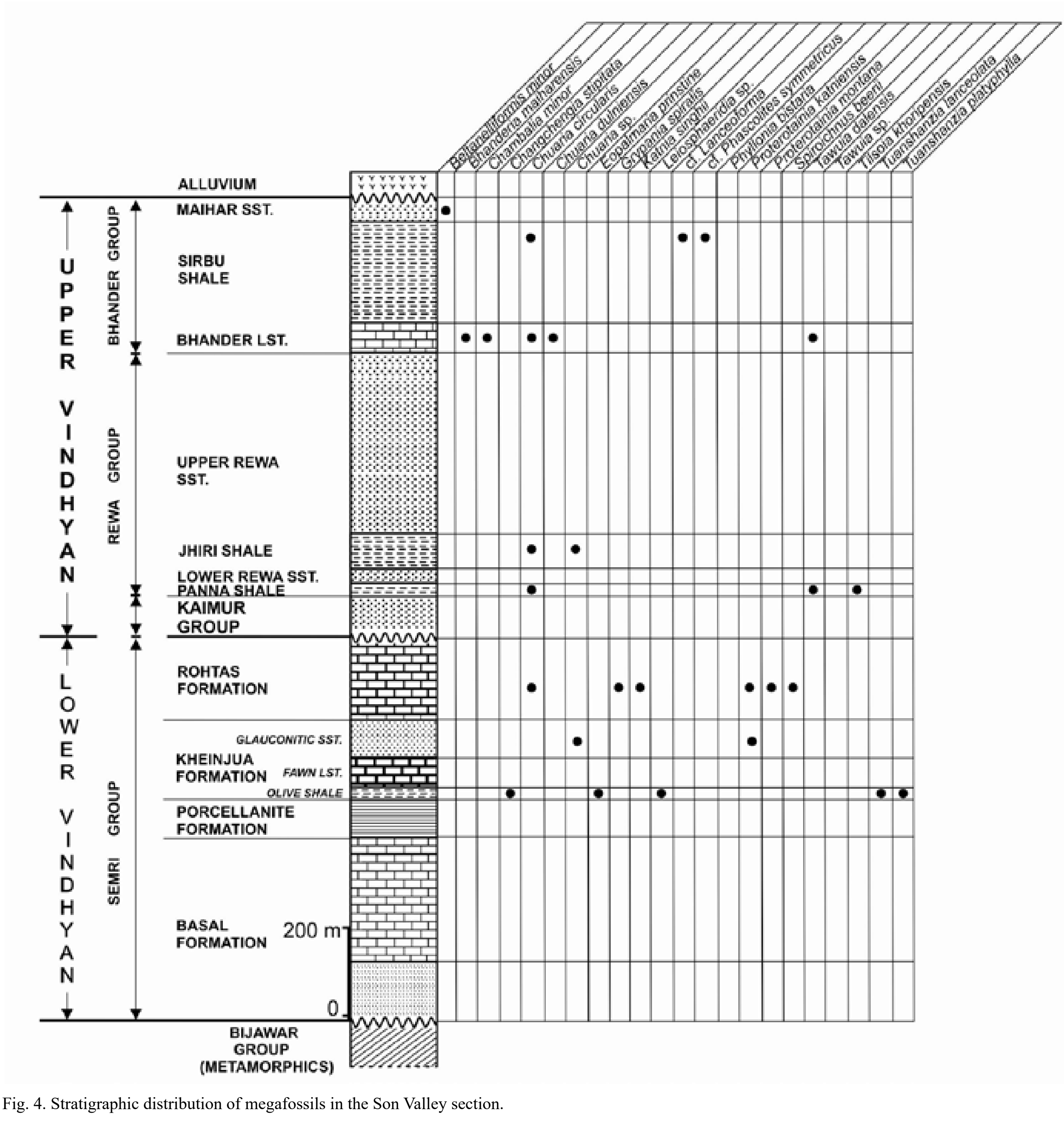

Fig. 4. Stratigraphic distribution of megafossils in the Son Valley section.

CONCLUSIONS

On the basis of the present review, it is contended that during the time of Vindhyan sedimentation the animal life did not exist except the occurrence of *Beltanelliformic minuta* in the youngest horizon of the Vindhyan Supergroup in the Son Valley section. Hence, the possibility of trace fossils in the form of scratch marks, burrows, trail marks, etc in the Vindhyan rocks is ruled out. Some structures which may have superficial resemblance with trace fossils must have been formed by inorganic processes. Any incorrect identification of biogenic structure can have serious implications for the science of evolutionary palaeobiology. In this context, Seilacher *et al.*'s (1998) report can be cited as an example, where one single incorrect identification of trace fossil of triploblastic animal could create utter confusion concerning the early evolution of animal life. Subsequently, this trace fossil proved to be a synearesis crack in a rock whose age is older than 1600 Ma (Kerr, 2002; Sharma, 2003; Kumar and Sharma, 2012).

Tables 3, 4 and 5 summarises the list of fossils and non-fossils reported from the Vindhyan Supergroup. Tables 3 & 4 give the edited list of fossils earlier reviewed by Venkatachala *et al*. (1996) and Sharma (2003). The list prepared by Venkatachala *et al*. (1996) have accepted only 13 reports out of the 48 reports as true fossils. But in the present work only five reports have

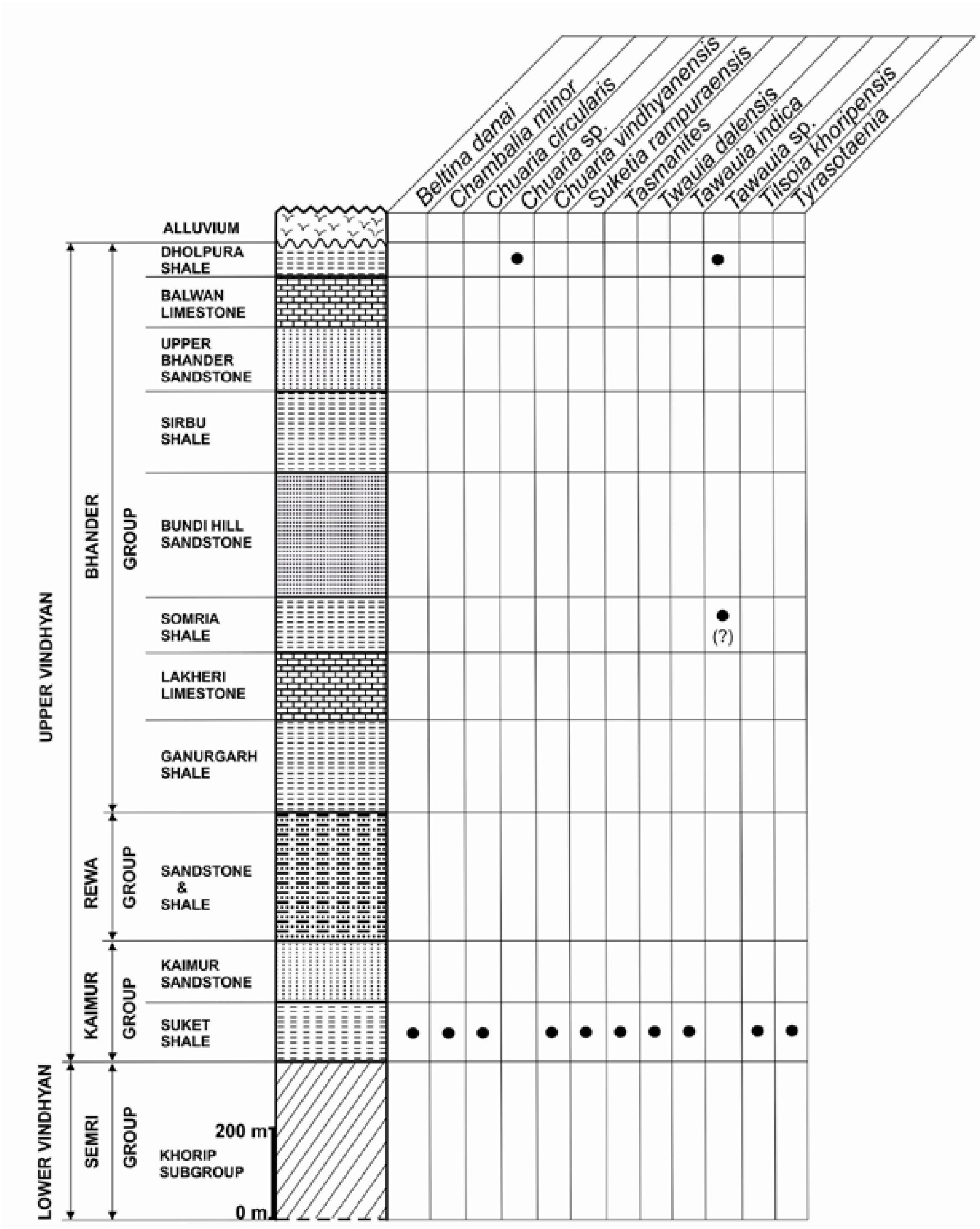

Fig. 5. Stratigraphic distribution of megafossils in the Chambal Valley section.

been accepted as true fossils out of these 48 reports. All reported fossils are carbonaceous in nature. Table 4 deals with the list prepared by Sharma (2003) for the fossils reported between 1990 and 2000. He evaluated 40 fossil reports out of which only eight were considered as fossils and Table 5 deals with reports published between 2000 and 2015. During this period only 61 fossil forms were recorded in 11 research papers. Out of which only 42 have been considered as true fossils and remaining 19 are considered as non-fossils.

Only carbonaceous compressions and impressions in both Lower and Upper Vindhyans are considered as true fossils which may have algal affinity.

Only one body fossil *Beltanelliformis minuta* reported by Kumar and Pandey (2008) from the Maihar Sandstone of Son Valley section can be accepted as fossil. It has good preservation, consistency in size and shape and has ecological association with microbial mat. This is the only noncarbonaceous fossil which is accepted as true fossil.

Final list of accepted mega-fossils is given below. It includes only those fossils which have been given names. The fossils are grouped in stratigraphic order. All are carbonaceous impressions and compressions except a body fossil *Beltanelliformis minor*. All fossil forms informally described as Form A, B, etc are not included in this list. The list is as follows:

Semri Group: *Chuaria circularis, Chuaria* sp., *Tawuia dalensis, Tawuia* sp. *Grypania spiralis, Spiroichnus beerii* (pseudomorph after *Grypania spiralis* like form), *Katnia singhii, Proterotainia montana, Proterotainia katniensis, Changchengia stipitata, Tuanshanzia platyphylla, Tuanshanzia lanceolata, Leiosphaeridia* sp., *Eopalmaria prinstine, Phyllonia bistaria*

Kaimur Group: *Chuaria circularis, Chuaria vindhyanensis, Tawuia dalensis, Tawuia indica, Suketea rampuraensis,Tilsoia khoripensis, Chambalia minor, Tyrasotaenia, Beltina danai,Tasmanites*

Rewa Group: *Chuaria circularis, Tawuia dalensis,Tilsoia khoripensis*

Bhander Group: *Chuaria circularis, Chuaria* sp., *.Chuaria dulniensis, Tawuia dalensis*, *Tawuia* sp., cf. *Phascolites symmetric,* cf. *Lanceoforma* sp., *Chambalia minor, Bhandaria maiharensis, Tyrasotaenia, Beltanelliformis minor* (Body fossil)

The stratigraphic distribution of megafossils in the Vindhyan Supergroup is given in Figs. 4 and 5 for the Son Valley and Chambal Valley sections, respectively.

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