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RECORD OF EDIACARAN COMPLEX ACANTHOMORPHIC ACRITARCHS FROM THE LOWER VINDHYAN SUCCESSION OF THE CHAMBAL VALLEY (EAST RAJASTHAN), INDIA AND THEIR BIOSTRATIGRAPHIC SIGNIFICANCE

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ABSTRACT

Abundant and well-preserved Ediacaran complex acanthomorphic acritarchs are recorded from the Lower Vindhyan succession in the recently drilled wells of CH-A, PL-A and SK-A in the Chambal Valley part of Vindhyan Basin. Important complex acanthomorphs recorded include various species of *Apodastoides, Appendisphaera, Cavaspina, Ceratosphaeridium, Densisphaera, Gyalosphaeridium, Knollisphaeridium, Sinosphaera* and *Tanarium.* Other significant forms are the species of *Lophosphaeridium, Obruchevella, Schizofusa* and *Vandalosphaeridium*. In addition, three new acanthomorph taxa, viz. *Archaeoacanthodiacrodium, Chambalasphaeridium* and *Triloboacanthosphaeridium* are identified. The above-mentioned complex acanthomorphs first appear in the basal part of the Lower Vindhyan Group, become abundant in the middle and finally disappear in the upper part of the Lower Vindhyan Group within the lower Suket Shale, suggesting an early Ediacaran age for the above succession. The middle and upper parts of the Suket Shale are dominated by *Lophosphaeridium rarum*, *Obruchevella* spp. and *Leiosphaeridia* spp. along with abundant filamentous microfossils, suggesting late Ediacaran age. The uppermost part of the Suket Shale and the overlying Upper Vindhyan succession are marked by the occurrence of *Asteridium tornatum, Comasphaeridium* sp., *Cristallinium cambriense, Dictyotidium birvetense* and *Lophosphaeridium tentativum* of Early Cambrian age.

The complex acanthomorph assemblages from the Lower Vindhyan succession of the Chambal Valley resemble the known Ediacaran complex acanthomorph assemblages from Yakutia (eastern Siberia), East European Platform, Amadeus Basin (Central Australia), eastern Officer Basin (South Australia), Yangtze Gorges (South China) and Krol Group (Lesser Himalaya, India). The above comparison favours an Ediacaran age for the subsurface Lower Vindhyan Group of the Chambal Valley, which until now has been dated as the Late Palaeoproterozoic-Mesoproterozoic on the basis of varied fossils and radiometric dating.

The occurrence of Ediacaran complex acanthomorphs in the Lower Vindhyan succession of the Chambal Valley offers two interpretations. Firstly, the Lower Vindhyan Group may be Ediacaran in age and corroborates the views given by some workers on its age. Another interpretation could be that the complex acanthomorphs might have evolved much earlier during Late Palaeoproterozoic-Early Mesoproterozoic time since the Lower Vindhyan succession are radiometrically dated ca 1730-1500 Ma. However, the presence of complex acanthomorph species, previously with known ranges restricted to Ediacaran successions, in the Lower Vindhyan succession of the Chambal Valley suggests that sedimentation in this part of the Vindhyan Basin commenced during Ediacaran time and ceased during the Early Cambrian. The Vindhyan succession of the Chambal Valley region appears different from the Vindhyan successions of Son Valley.

Keywords: Ediacaran complex acanthomorphs, Lower Vindhyan Group, Chambal valley, east Rajasthan, India

INTRODUCTION

The Vindhyan Basin is a large intracratonic Proterozoic sedimentary basin located in the northern parts of India. It extends from east Rajasthan (Chambal Valley) in the west to the southern Uttar Pradesh and western Bihar (Son Valley) in the east. (Fig.1a). The basin-fills include a thick Proterozoic sedimentary sequence of mixed carbonate-siliciclastic rocks which are classed as the Vindhyan Supergroup (Fig. 2). It rests over the Paleoproterozoic Bundelkhand Granitic Complex (BGC)/Bijawar Group in Son Valley and Pre-Aravalli rocks/ Berach Granite in Chambal Valley, and is overlain by the Late Cretaceous Deccan Traps (Fig. 1a). The geological age of this distinctive Proterozoic succession has long been a subject of major controversy mainly due to absence or paucity of fossils and varied absolute age datings.

Controversy regarding the age of the Vindhyan Supergroup

Diverse and disputed ages have been assigned for the Vindhyan Supergroup ranging from Late Paleoproterozoic (ca 1730 Ma) to Early Paleozoic (Cambrian-Ordovician) on the basis of records of controversial fossils of diverse aspects and varied radiometric datings at different stratigraphic levels. In the majority of the studies, a long age-range from Late Paleoproterozoic to Late Neoproterozoic (ca 1730-542 Ma) has been assigned with Ediacaran as its upper age limits (Prasad *et al.,* 2005; Prasad, 2007; Kumar and Sharma, 2012). Biostratigraphic evidences for the above age is based on stromatolites (Kumar, 1980, 1982), macro-megafossils (Sharma *et al.,* 1992; De, 2006), triploblastic animal trace-fossils (Seilacher *et al.,* 1998), and acritarchs and associated organic-walled microfossils (Maithy, 1992; Venkatachala *et al.*, 1996; Sharma *et al.,* 1992; Kumar and Srivastava, 1997; Maithy and Babu, 1993, 1997; Prasad *et al.,* 2005; Prasad, 2007).

Absolute age evidences for the Vindhyan Supergroup are available through the radiometric dating at different stratigraphic levels (Vinogradov *et al.,* 1964; Tugarinov *et. al.,* 1965; Crawford and Compston, 1970; Paul *et al.,* 1975; Kreuzer *et al.,* 1977; Srivastava and Rajagopalan, 1988; Kumar *et al.,* 1993, Rasmussen *et al.* 2002; Ray *et al.,* 2002, 2003; Kumar *et al.,* 2001; Sarangi *et al.,* 2004; Gregory *et al.,* 2006; Malone *et al.,* 2008) that range from ca 1730 Ma to 550 Ma. However, Ray *et al.* (2003) and Malone *et al.* (2008) are of the opinion that Vindhyan sedimentation terminated at ca 650 Ma and 1020 Ma respectively.

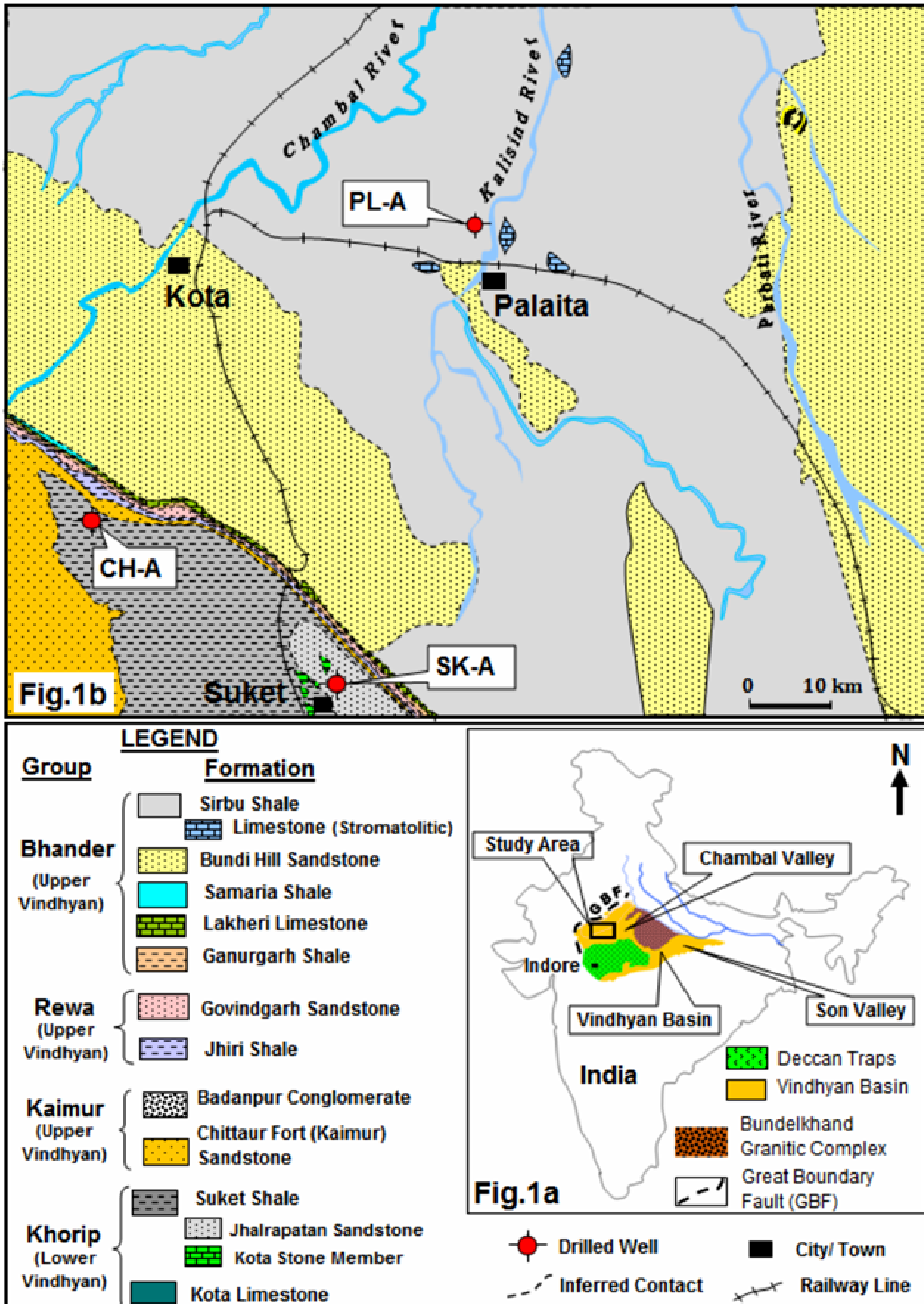


Fig. 1 a-b. 1a. Generalised map of India, showing the setting of Vindhyan Basin and location of studied areas in the Chambal valley (in Box). 1b. Detailed geological map of the Kota-Bundi areas of Chambal Valley, east Rajasthan, India (after Prasad, 1984), showing the exposures of various lithounits of the Vindhyan Supergroup and locations of wells CH-A, SK-A and PL-A.

In the Son Valley part of the Vindhyan Basin, the Kajrahat Limestone, representing lower part of the Lower Vindhyan (Semri) Group, is dated 1014±18 Ma by Rb-Sr method (Bansal *et al.,* 1999) and 1729±110 Ma by U-Pb method (Sarangi *et al.,* 2004). The overlying Deonar Formation (Chopan Porcellanite) of the Semri Group is dated 617 ± 3.5 Ma through Ar^{40}/Ar^{39} method by Banerjee and Frank (1999). This unit has also been dated as 1631±5 Ma (Ray *et al.,* 2002) and 1628 ± 8 Ma (Rasmussen *et al.,* 2002) through U-Pb Zircon method. Similarly, the glauconitic sandstone of the Rampur Formation (Kheinjua Subgroup) is also variously dated by Vinogradov *et al.* (1964) as 1110 ± 60 Ma, which was later recalculated by Kreuzer *et al.* (1977) as 1080± 40 Ma. Rasmussen *et al*., (2002) dated the above lithounit as 1599 ± 8 by U-Pb methods. Ray *et al.* (2003) and Sarangi *et al.* (2004) dated the uppermost lithological unit of the Lower Vindhyan Group, viz. Rohtas Limestone as 1601± 130 Ma and 1599 ± 48 Ma by U-Pb method. Crawford and Compston (1970) dated the Kimberlite pipe intruding the upper Kaimur Sandstone of Majhgawan mine at the Panna town as 1140 ± 12 Ma by Rb-Sr method. This lithounit has also been dated as 1073± 13 Ma on the basis of Ar^{40}/Ar^{39} method (Gregory *et al*., 2006). Crawford and Compston (1970) dated the Maihar Sandstone of Bhander Group as 550 Ma by Rb-Sr method. Friedman *et al.* (1996) and Friedman and Chakraborty (1997) suggested the Precambrian-Cambrian boundary at the base of Sirbu Shale (Magardha Limestone) within the Bhander Group on the basis of $\delta^{13}C$ data, whereas Rathore *et al.* (1999) dated the Sirbu Shale as 741 ± 9 Ma by K-Ar method.

In the Chambal Valley part of the Vindhyan Basin, Vinogradov *et al.* (1964) dated the lower Kaimur Sandstone and upper Kaimur Sandstone of the Chittorgarh area as 940± 30 Ma and 910± 30 Ma respectively by K-Ar method. Kreuzer *et al.* (1977) revised the Vinogradov *et al.* (1964) dating of the Kaimur Sandstone as 890± 40 Ma on the basis of newly recommended decay constants (λ). Srivastava and Rajagopalan (1988) dated the Upper Rewa Sandstone (Govindgarh Sandstone) and Lower Bhander Sandstone (Bhander Group) of the Rawatbhata area (Chambal Valley, east Rajasthan) as 710-675 Ma and 625± 24 Ma respectively by Fission-Track (F-T) method. Malone *et al.* (2008) dated the upper Bhander Sandstone of Kota area (Chambal Valley, east Rajasthan) as 1020 Ma by detrital Zircon U-Pb method.

It is apparent from the above review that the radiometric data from different lithological units of the Vindhyan Supergroup are quite diverse and inconsistent, and gave varied ages for the Vindhyan Supergroup that range from Late Paleoproterozoic to Late Neoproterozoic (Ediacaran).

Nevertheless, delimiting the upper age limit of the Vindhyan Supergroup as Late Mesoproterozoic (~1020 Ma; Malone *et al.,* 2008) or Middle to Late Neoproterozoic (750-650 Ma; Ray *et al.,* 2002; Ray *et al.,* 2003) through radiometric dating has not been accepted by several workers from fossil evidences, that suggest a Late Neoproterozoic (Ediacaran) age for the Lower Vindhyan Group and Early Palaeozoic (Cambrian-Ordovician) for the Upper Vindhyan Group. Salujha *et al.* (1971a, 1971b), based on records of small acanthomorphs (*Micrhystridium, Baltisphaeridium*), herkomorphs (*Cymatiosphaera, Dictyotidium, Priscogalea*) and ornamented sphaeromorphs (*Lophosphaeridium* spp.) from the Rohtas Limestone-Suket Shale (Lower Vindhyan Group) and overlying sediments of the Kaimur-Rewa-Bhander subgroups (Upper Vindhyan Group) in the Son and Chambal valleys suggested that the Upper Vindhyan succession represented the Cambrian-Ordovician in this basin. Later records of Early Cambrian small shelly fossils (SSFs), calcareous skeletal algae, animal embryo, small acanthomorphs, scolecodonts, sponge spicules, carbonaceous metaphytes and trace-fossils (Azmi, 1998; Azmi *et al.,* 2007) from the Rohtas Subgroup, with demarcation of the Precambrian-Cambrian boundary within the upper parts of the Rohtas Limestone, led to a reconsideration of the existing view of a Late Paleoproterozoic-Early Mesoproterozoic age for the Lower Vindhyan Group. However, records of the above fossil groups of the Precambrian-Cambrian transition aspect from the Rohtas Subgroup (Azmi, 1998; Azmi *et al.,* 2007) were questioned by several workers (Kumar, 2008; Kumar and Sharma, 2012). Bengtson *et al.* (2009) corroborated the Azmi's findings as real based on the reproducibility of the above fossils from the localities from where Azmi and his coworkers (1998, 2007) had earlier reported. However, Bengtson *et al.* (2009), giving more weightage to radiometric datings, opined that the above fossils might have existed even during Late Paleoproterozoic-Early Mesoproterozoic time.

Additional important records of Ediacaran megafossil *Spriggina* (?) from the Palkawan Shale (Porcellanite Formation, Lower Vindhyan Group) in the Son Valley (Kathal *et al.*, 2000) and acanthomorph acritarch *Cymatiosphaeroides kullungii* of Cryogenian age (Middle Neoproterozoic) from the Chitrakoot Formation, Lower Vindhyan Group (Anbarasu, 2001) also favoured Middle to Late Neoproterozoic (Cryogenian-Ediacaran) age for the Lower Vindhyan succession. The record of helically coiled filamentous microfossils of *Obruchevella* (*O. parva* and *O. pusilla*) of Ediacaran aspect from the Salkhan Limestone (Lower Vindhyan Group) by Rai and Singh (2004) further strengthened the views of Ediacaran age for the Lower Vindhyan succession. Thus, controversy regarding the age of the Vindhyan Supergroup remains unresolved, and various workers are regularly contributing to resolve its age problem.

In the present contribution, we present the complex acanthomorphic acritarchs as evidence of Ediacaran age for the Lower Vindhyan succession of the Chambal valley part of the Vindhyan Basin.

New record of complex acanthomorphic acritarchs from the Lower Vindhyan Group of Chambal Valley

Recently (2012-13), Oil and Natural Gas Corporation Limited (ONGC), India, drilled three exploratory wells, viz. CH-A, SK-A and PL-A in the Chambal Valley parts of the Vindhyan Basin (Figs. 1b, 2) to seek the subsurface geological information on the Vindhyan succession. In course of biostratigraphic studies on these wells, authors observed the abundant occurrence of well-preserved complex acanthomorphs of relatively larger size of characterstic Ediacaran aspect from the Lower Vindhyan sedimentary rocks (Pl. I-VIII), which, until now, are considered as the Late Paleoproterozoic-Mesoproterozoic in age.

The occurrence of complex acanthomorphs, having varied homomorphic to heteromorphic processes on their vesicles, with unusually larger size, was an important biotic event during Late Neoproterozoic (Ediacaran) time according to Moczydlowska (2005). According to Knoll and Walter (1992), Grey (2005) and Moczydlowska (2005) these unusual complex acanthomorphs first appear above the Cryogenian-Ediacaran boundary, were very short lived in a period between ca 620-550 Ma and disappeared prior to the dawn of Cambrian (ca 542 Ma) during the end phase of Ediacaran. Complex acanthomorphs have been recorded from the Ediacaran sequences of Siberian Platform (Pyatiletov and Rudavskaya, 1985; Rudavskaya and Vasileva, 1989; Kolosova, 1991; Moczydlowska *et al.,* 1993; Vidal *et al.,* 1993; Moczydlowska and Nagovitsin, 2012), East European Platform (Vorob'eva *et al.,* 2009a, 2009b), China (Yin, 1985, 1986, 1987; Zhang, 1984; Zhang *et al*., 1998; Yuan and Hofmann, 1998; Liu *et al.,* 2013, Liu *et al.,* 2014; Xiao *et al.,* 2014), Australia (Zang, 1992; Zang and Walter, 1992; Grey, 1998, 2005; Willman *et al.,* 2006; Willman and Moczydlowska*,* 2008; Willman and Moczydlowska*,* 2011) and Lesser Himalaya, India (Tiwari and Knoll, 1994).

In this contribution, the authors have documented the well-preserved and taxonomically diverse complex acanthomorphic acritarchs of Ediacaran aspect along with other associated acritarchs and filamentous microfossils (Pl. I-IX) from the subsurface Lower Vindhyan sedimentary rocks encountered in CH-A (depth-interval 84-1871m), SK-A (72-1752m) and PL-A (2750-3305m) wells drilled in western parts of the Vindhyan Basin (Chambal Valley) in east Rajasthan (Figs. 1b,2,3,4). The present record of complex acanthomorphs provides new biostratigraphic evidence of Ediacaran age for the Lower Vindhyan sedimentary rocks of the Chambal Valley. Additionally, the occurrence of ornamented sphaeromorphs, helically-coiled filamentous microfossils, small acanthomorphs and herkomorphs of late Ediacaran-Early Cambrian age in the middle, upper and uppermost parts of the Suket Shale (Lower Vindhyan Group) and the overlying Kaimur, Rewa and Bhander subgroups (Upper Vindhyan Group) are also listed and briefly discussed to understand the total age-range of the Vindhyan Supergroup.

GEOLOGICAL SETTING AND LITHOSTRATIGRAPHY OF CHAMBAL VALLEY

The Chambal Valley area in east Rajasthan (India) represents the western part of the great Vindhyan Basin. Its western limit is marked by Great Boundary Fault (GBF), whereas eastern boundary is marked by the exposures of Bundelkhand Granitic Gneiss (Fig. 1a). Detailed accounts on the geology of Chambal Valley parts of the Vindhyan Basin are available through the works of Mallet (1869), Heron (1932) and Auden (1933). A number of lithostratigraphic classifications were proposed for the Vindhyan Supergroup; however Auden's (1933) classification is widely accepted. This classification was later modified by Sastri and Moitra (1984) and Prasad (1984) according to the latest Code of Stratigraphic Nomenclature, and the same is followed here. The entire Proterozoic succession of the Vindhyan Basin, occurring between the Paleoproterozoic Bundelkhand Granitic Complex-Bijawar/ Pre-Aravalli-Aravalli groups and Late Cretaceous Deccan Traps, is classed as the Vindhyan Supergroup (Fig. 2). It is subdivided into two groups, the older one as the Lower Vindhyan Group and the younger one as the Upper Vindhyan Group. The sedimentary rocks of Lower Vindhyan Group are also referred to as the Semri Group. In the Chambal Valley region, the Lower Vindhyan Group (Semri Group) is subdivided into four subgroups, viz. Satola, Sand, Lasrawan and Khorip which are further classified into a number of lithounits (Fig. 2). The Upper Vindhyan Group is also subdivided into Kaimur, Rewa and Bhander subgroups. The Nimbahera Limestone and Suket Shale represent the youngest units in the Lower Vindhyan Group in Chambal Valley. Their equivalents in the Son Valley are the Rohtas Limestone and Bhagwar Shale. The Kaimur, Rewa and Bhander subgroups of the Upper Vindhyan Group are also subdivided into a number of lithounits (Fig. 2).

MATERIALS AND METHODS

Cuttings samples undertaken for studies are from the Lower Vindhyan sedimentary rocks of wells CH-A (depth-interval 30-1871m), SK-A (surface-1752m) and PL-A (2530-3305m) that recorded rich assemblages of Ediacaran complex acanthomorphs and other associated organic-walled microfossils (Pl. I-IX). The exploratory wells CH-A and SK-A were drilled on the Suket Shale outcrops which represent the youngest unit of the Lower Vindhyan Group and drilled down to the Precambrian basement (Fig. 2). The well PL-A was drilled on the Maihar Sandstone, representing youngest unit of the Vindhyan succession, and intersected the various lithounits of Bhander, Rewa, Kaimur subgroups of the Upper Vindhyan Group and sedimentary rocks of the Lower Vindhayan Group (Semri Group) in descending order. This well was terminated in the Precambrian basement at 3367.66m with basement top at 3305m depth (Fig. 2). Thus, samples from the sedimentary rocks of the Upper Vindhyan Group (30-2530m) were also studied from well PL-A to understand the stratigraphic distribution pattern of complex acanthomorphs and other associated acritarchs in the entire Vindhyan succession.

The conventional palynological maceration techniques and the modified maceration techniques proposed by Grey (1999) were applied for the extraction of acid resistant organic-walled microfossils. Initially samples were broken upto size of 2-3mm and then subjected to treatment by hydrochloric acid (HCl) of Laboratory Reagent (LR) grade (10%) for dissolution of carbonates and hydrofluoric acid (HF) of 40% concentration for dissolution of silicates. Palynological residues are isolated by filtering the residue on 10-15μm sieve mesh. The isolated palynological residues are fixed on the glass slides by polyvinyl alcohol and slides were mounted by coverslips using Canada Balsum. Palynological slides were examined under the Lietz Wetzlar Orthoplan transmitted light microscope. Microphotographs are recorded with digital camera of Leica DFC425.

Slides of all the studied samples that have documented and illustrated complex acanthomorphs are stored in the Repository Section of Palynology Division at KDM Institute of Petroleum Exploration, ONGC, Dehradun (India) under the Reg. No. KDMIPE/Paly/Chambl.Vindh./13-14/1. Documented microfossils can be located/ retrieved with the address given against each illustration. Individual specimen is addressed after the well name, well-depth and slide no. 1 or 2, and followed by the England Finder (EF) reading. For example, specimen of *Appendisphaera tabifica* of Pl. II, Fig. 6 can be located in the slide of well CH-A, depth-int. 1810-15m, slide no. 2, reading EF. L63/1

The important complex acanthomorph taxa recorded from the Lower Vindhyan succession of above wells from Chambal Valley are documented and illustrated through microphotographs in photoplates (Pl. I-VIII). The stratigraphic distribution of important complex acanthomorphs and associated age marker other organic-walled microfossils in CH-A and PL-A wells are presented through the frequency distributions (Figs. 3, 4), with identification of acritarch assemblages and their inferred age.

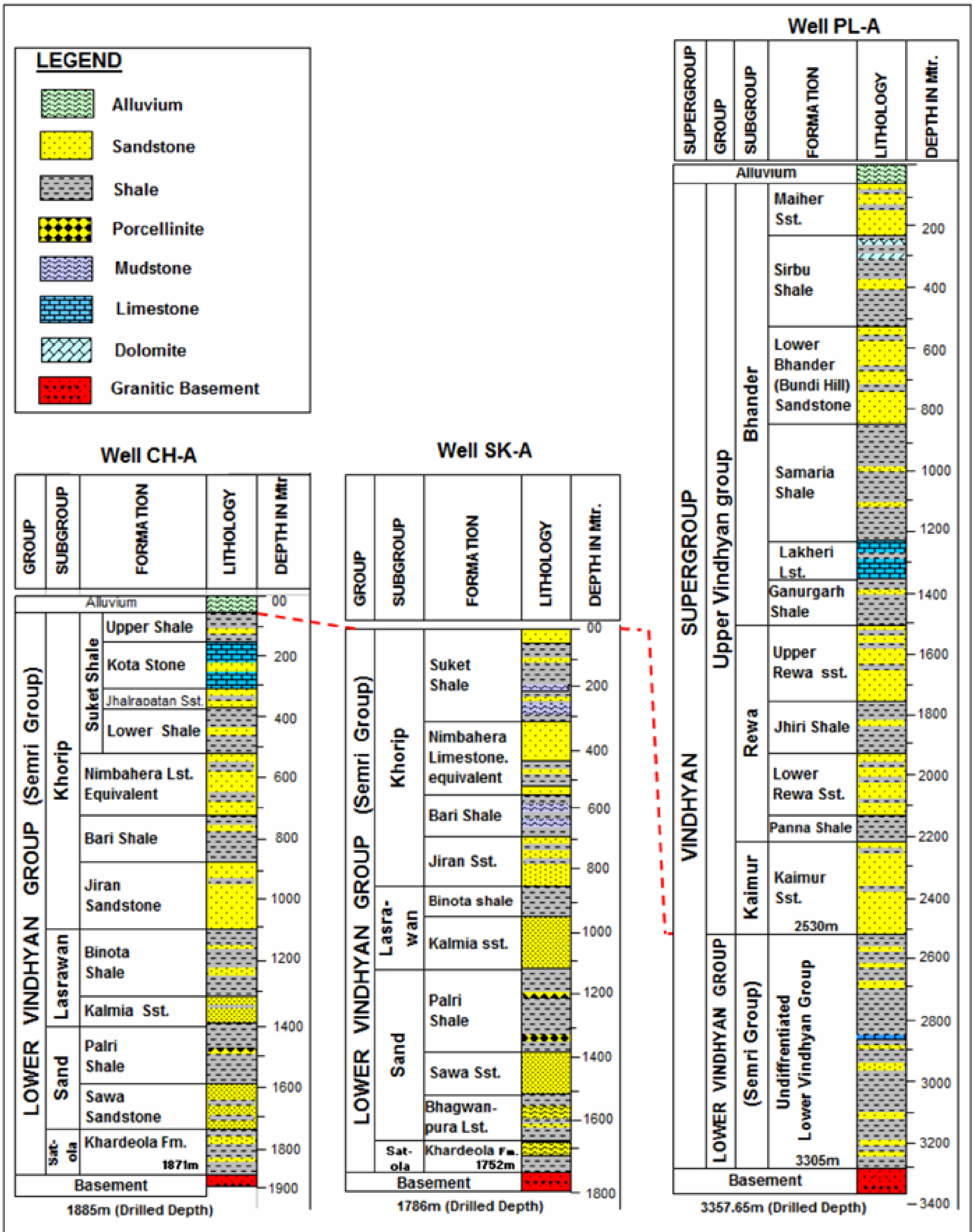


Fig. 2. Generalised lithostratigraphic successions of the Vindhyan Supergroup encountered in wells CH-A, SK-A and PL-A, showing detailed lithological features of the Lower Vindhyan sedimentary rocks (which recorded Ediacaran complex acanthomorphs) and the Upper Vindhyan succession in PL-A (that yielded Early Cambrian acritarchs).

COMPLEX ACANTHOMORPH ASSEMBLAGES FROM LOWER VINDHYAN GROUP OF CHAMBAL VALLEY

The shale, siltstone and carbonaceous shale layers of various lithounits of the Lower Vindhyan Group in three sampled wells of CH-A, SK-A and PL-A (Fig. 2) recorded fair to rich occurrence of complex acanthomorphs. Twenty three species belonging to thirteen acanthomorphic acritarch genera are recorded from the Lower Vindhyan sedimentary rocks in the three studied wells, along with other age significant organic-walled microfossils (Pl. I-IX). The recorded complex acanthomorphs are listed below. New acanthomorph taxa and some known taxa are briefly described in the Appendix A part of the text.

List of recorded large and complex acanthomorphs

Apodastoides aff. *A. verobturatus* Grey, 2005 (Pl. I, figs. 1-2).

Appendisphaera aff. *A. anguina* Grey, 2005 (Pl. I, figs. 3- 4).

Appendisphaera? brevispina Liu, Xiao, Yin, Chen, Zhou and Li, 2014 (Pl. I, figs. 5 - 6).

A. fragilis Moczydlowska, Vidal and Rudavskaya (1993) emend. Moczydlowska, 2005 (Pl. II, figs. 1 - 2).

A. grandis Moczydlowska, Vidal and Rudavskaya (1993) emend. Moczydlowska, 2005 (Pl. II, figs. 3 - 4).

A. tabifica Moczydlowska, Vidal and Rudavskaya (1993) emend. Moczydlowska, 2005 (Pl. II, figs. 5 – 6; Pl. III, figs.1 - 2).

A. tenuis Moczydlowska, Vidal and Rudavskaya (1993) emend. Moczydlowska, 2005 (Pl. III, figs. 3 - 6).

Archaeoacanthodiacrodium flexispinosum Prasad and Asher, n. gen et sp. (Pl. IV, figs. 1- 4).

Cavaspina acuminata (Kolosova, 1991) Moczydlowska, Vidal and Rudavskaya, 1993 (Pl. IV, figs. 5 - 6).

C. basiconica Moczydlowska, Vidal and Rudavskaya, 1993 (Pl. IV, figs. 7 - 8).

Ceratosphaeridium glaberosum Grey, 2005 (Pl. IV, figs. 9 - 10).

Chambalasphaeridium guchchaensis Prasad and Asher, n. gen et sp. (Pl. V, figs. 1 - 4).

Densisphaera arista Nagovitsin and Moczydlowska, in Moczydlowska and Nagovitsin, 2012 (Pl. V, figs. 5 - 6).

Densisphaera fistulosa Nagovitsin and Moczydlowska, in Moczydlowska and Nagovitsin, 2012 (Pl. VI, figs. 1 - 2).

Gyalosphaeridium multispinulosum Grey, 2005 (Pl. VI, figs. 3 - 4).

G. pulchrum Zang in Zang and Walter (1992) emend. Grey, 2005 (Pl. VI, figs. 5 - 6).

Knollispharidium triangulum (Zhang *in* Zhang and Walter, 1992; Willman and Moczydlowska, 2008) emend. Xiao, Zhou, Liu, Wang and Yuan, 2014 (Pl. VII, figs. 1 - 2).

Schizofusa risoria Grey, 2005 (Pl. VII, figs. 9 - 10).

Sinosphaera rupina (Zhang, Yin, Xiao and Knoll, 1998) emend. Liu, Xiao, Yin, Chen, Zhou and Li, 2014 (Pl. VII, 3 - 5).

Tanarium anozos Grey, 2005 (Pl. VII, figs. 6 - 7).

T. conoideum Kolosova (1991) emend. Moczydlowska, Vidal and Rudavskaya, 1993 (Pl. VII, fig. 8).

T. tuberosum Kolosova (1991) emend. Moczydlowska, Vidal and Rudavskaya, 1993 (Pl. VIII, figs. 1 - 2).

Triloboacanthosphaeridium tripartita Prasad and Asher, n. gen et sp. (Pl. VIII, figs. 3 - 6).

List of associated important acritarchs and associated organic-walled microfossils

Cristallinium cambriense (Slavikova 1968) Vanguestaine, 1978 (Pl. VIII, figs. 7- 8).

Cristallinium cf. *C. cambriense* (Slavikova 1968) Vanguestaine, 1978 (Pl. VIII, fig. 9).

Dictyotidium birvetense Paskevicieue, 1979 (Pl. IX, figs. 1 - 2).

Dictyotidium cf. *D. birvetense* Paskevicieue, 1979

Lophosphaeridium jansoniusii Salujha, Rahman and Arora, 1971a (Pl. IX, fig. 6).

Lophosphaeridium rarum Timofeev, 1958 (Pl. IX, figs. 7 - 8).

L. tentativum Volkova, 1969 (Pl. IX, fig. 10).

Asteridium lanatum (Volkova, 1969) Moczydlowska, 1991

A. tornatum (Volkova, 1968) Moczydlowska, 1991.

Obruchevella valdaica (Shepeleva, 1974 ex Aseeva, 1974) Jankauskus, Mikhailova and German, 1989 in Jankauskus, 1989 (Pl. IX, fig. 11)

Obruchevella parva Reitlinger, 1959 (Pl. IX, fig. .12)

Vandalosphaeridium reticulatum (Vidal 1976) Vidal, 1981 (Pl. IX, figs. 13 -14).

In addition to the above illustrated taxa, forms, such as *Kildinosphaera verrucata* Vidal in Vidal and Siedlecka (1983), *K. granulata* Vidal in Vidal and Siedlecka (1983), *Leiosphaeridia jacutica* (Timofeev 1958) Mikhailova and Jankuaskas (1989), *L. minutissima* (Naumova 1949) Jankauskas in Jankuaskas *et al.* (1989), *L. pellucida* Salujha, Rehman and Arora (1971a), *L. tenuissima* Eisenack (1958), *Pterospermopsimorpha insolita* Timofeev (1969), *P. saccata* Yin (1987), *Simia annulare* (Timofeev, 1969) Mikhailova and Jankuaskas (1989), *Satka squamifera* Pyalitatov (1980), *Trachysphaeridium laminaritum* (Timofeev, 1966) Vidal (1976) and *Lophosphaeridium jansoniusii* Salujha, Kindra and Rehman (1971) are also abundantly present in the Lower Vindhyan sedimentary rocks of above mentioned wells.

Various species of filamentous and helically coiled microfossils, such as *Siphonophycus septatum* Schopf (1968) Knoll *et al.* (1991), *S. robustum* Schopf (1968) Knoll *et al.* (1991), *S. rugosum* Maithy (1975) Hofmann and Jackson (1994), *S. kestron* Schopf (1968), *Tortunema pseudoseptata* German (1990) Butterfield *et al*. (1994), *Polythrichoides lineatus* German (1974) Knoll *et al.* (1991), *Obruchevella valdaica* (Shepeleva ex Aseeva, 1974) Yankauskas, Mikhailova and German (1989), *O. delicata* Reitlinger (1948) and *O. parva* Reitlinger (1959) are also frequently recorded in the Lower Vindhyan sedimentary rocks.

It is noteworthy that middle and upper parts of Suket Shale (Lower Vindhyan Group) in the studied drillholes are dominated by *Leiosphaeridia* spp., *Lophosphaeridium jansoniusii*, *L. rarum*, *Obruchevella* spp. along with abundant filamentous microfossils of larger size, suggesting late Ediacaran age (Figs. 3, 4). The uppermost parts of Suket Shale (youngest lithounit of the Lower Vindhyan Group) and the overlying Upper Vindhyan sedimentary rocks of Kaimur, Rewa and Bhander subgroups in wells CH-A and PL-A recorded acritarchs of Early Cambrian aspect (Figs. 3, 4) which are very common in the Early Cambrian successions of European Platforms (Volkova *et al*., 1979, 1983; Moczydlowska, 1991; Sergeev, 2009) and other parts of the world. These forms are *Asteridium lanatum* Volkova (1968), *Comasphaeridium* sp. cf. *C. strigosum* Yankauskas (1976)

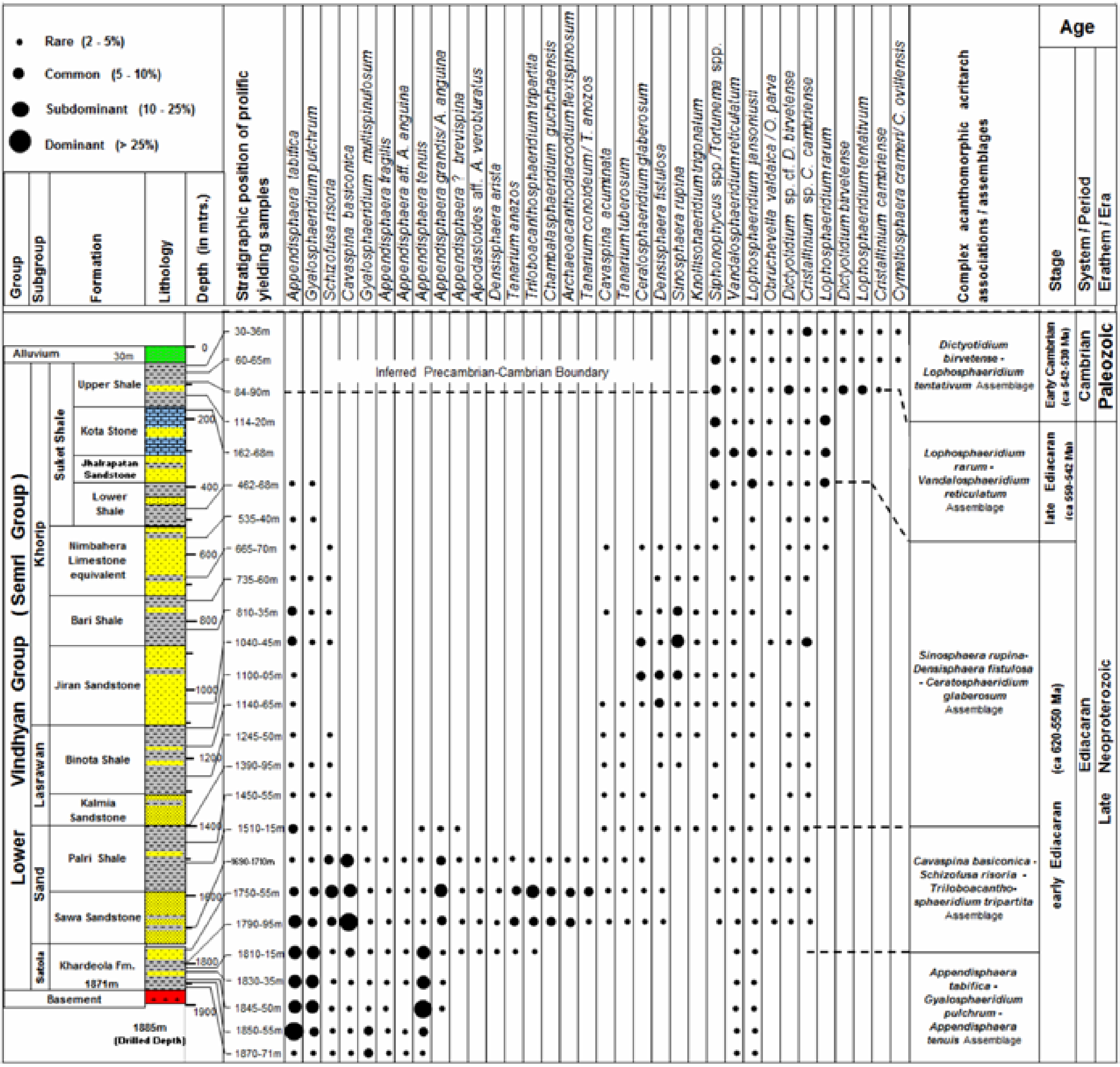


Fig. 3. Stratigraphic distribution of selected Ediacaran complex acanthomorphs and associated organic-walled microfossils in the Lower Vindhyan sedimentary rocks of well CH-A (Chambal valley), east Rajasthan, with recognised acanthomorphic acritarch assemblages and inferred ages.

Downie (1982), *Cymatiosphaera crameri* Slavikova (1968) *Cristallinium cambriense* Slavikova (1968) Vanguestaine (1978), *Cristallinium ovillense* (Cramer and Diez, 1972b) Fensome *et al.* (1990), *Cymatiosphaera ovillensis* Cramer and Diez (1972), *Dictyotidium birvetense* Paskevicieue (1979), *Lophosphaeridium tentativum* Volkova (1968) and *L. truncatum* Volkova (1969). These acritarch taxa are not illustrated here, and will be presented in future works by the authors.

DISCUSSION

Stratigraphic distribution of complex acanthomorphs in the Lower Vindhyan Group of the Chambal Valley

The present record of complex acanthomorphs of Ediacaran aspect from the Lower Vindhyan sedimentary rocks of wells CH-A, SK-A and PL-A in Chambal Valley part of the Vindhyan Basin (Pl. I-VIII) is very important. It has provided a new biostratigraphic data that has given fresh impetus for dating the Vindhyan sedimentary rocks and infering the depositional history of the Vindhyan succession in the Chambal Valley part of the Vindhyan Basin. The most significant finding is the abundant occurrence of complex acanthomorphs in the subsurface sedimentary rocks of the Lower Vindhyan Group, having relatively larger size than their Early Palaeozoic (Cambrian) counterpart which characterise the Ediacaran acritarch assemblages world-wide. These include *Apodastoides verobturatus, Appendisphaera* aff. *A. anguina, Appendisphaera? brevispina, A. fragilis, A. grandis, A. tabifica, A. tenuis, Archaeoacanthodiacrodium flexispinosum, Cavaspina acuminata, C. basiconica, Ceratosphaeridium glaberosum,*

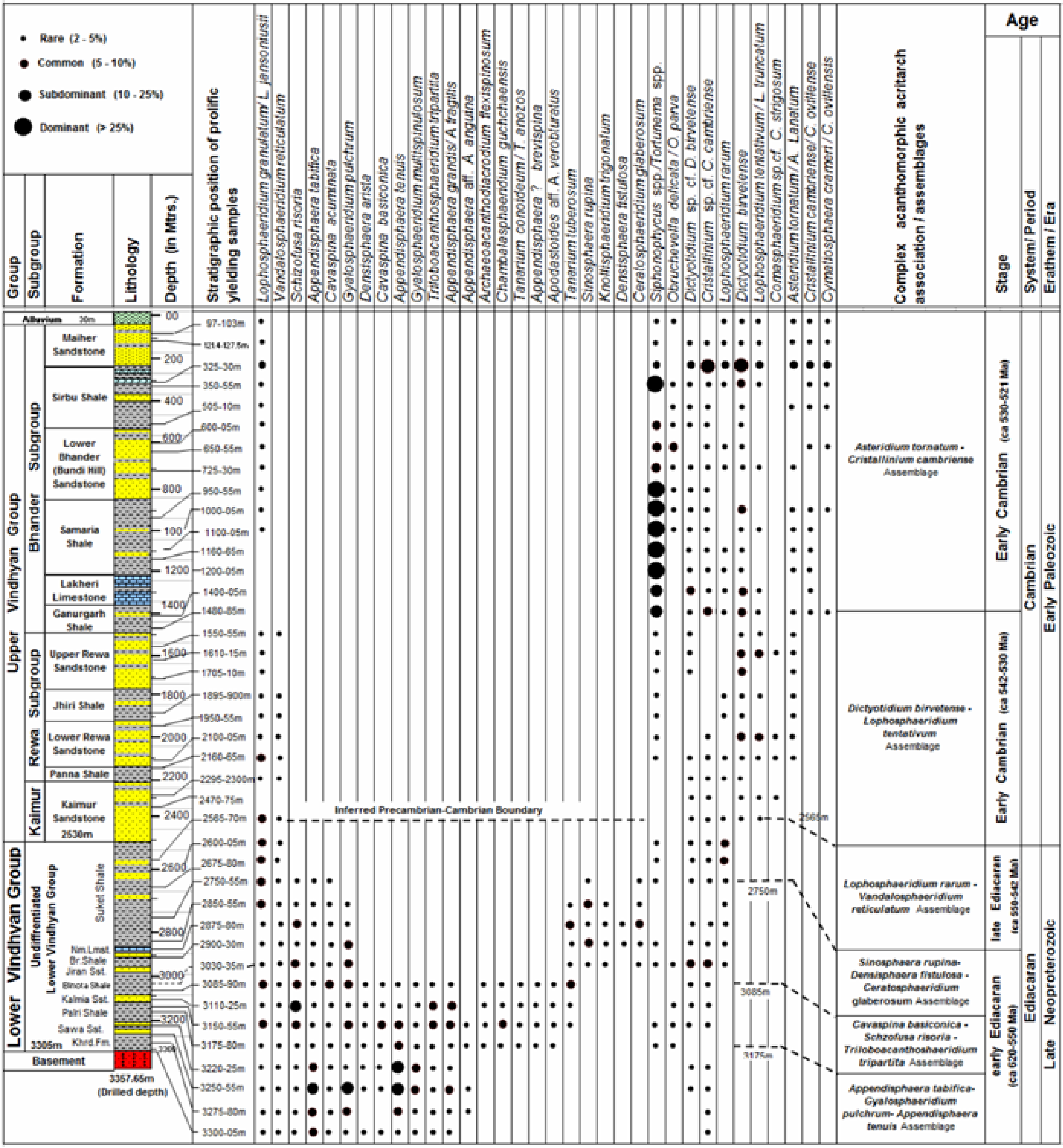


Fig. 4. Stratigraphic distribution of selected Ediacaran complex acanthomorphs in the Lower Vindhyan succession and Early Cambrian acritarchs and associated organic-walled microfossils in the Upper Vindhyan sedimentary rocks of well PL-A (Chambal Valley), east Rajasthan, with recognised acanthomorphic acritarch assemblages and inferred ages.

Chambalasphaeridium guchchaensis, Densisphaera arista, D. fistulosa, Gyalosphaeridium multispinulosum, G. pulchrum, Knollisphaeridium triangulum, Sinosphaera rupina, Tanarium anozos, T. conoideum, *T. tuberosum* and *Triloboacanthosphaeridium tripartita.* In addition to the above, other age potential organic-walled microfossil taxa that generally occur during Ediacaran are also recorded. These are *Lophosphaeridium rarum, Obruchevella delicata, O. parva, Schizofusa risoria* and *Vandalosphaeridium reticulatum.* The bulk of the microfossil assemblages (50-60%), recovered from the Lower Vindhyan succession in above wells are represented by various species of *Kildinosphaera, Leiosphaeridia, Lophosphaeridium, Pterospermopsimorpha, Satka, Simia, Siphonophycus, Synsphaeridium* and *Trachysphaeridium*. The other 40-50% of the population is represented by the complex acanthomorphs and other associated marker Ediacaran taxa mentioned above. Rare occurrence of herkomorphs referable to *Cristallinium, Cymatiosphaera, Dictyotidium* and small acanthomorphs (*Asteridium*) are also recorded (Figs. 3, 4).

In all the three studied exploratory wells of CH-A, SK-A and PL-A, complex acanthomorphs first appear in the basal parts of the Lower Vindhyan sedimentary rocks in the Khardeola Formation (Figs. 3, 4). They become abundant in upper parts of the Khardeola Formation and in the overlying Bhagwanpura Limestone, Sawa Sandsone and Palri Shale lithounits of the Sand Subgroup. Their population becomes common to poor in the succeeding Kalmia Sandstone, Binota Shale and Jiran Sandstone. Their frequencies are almost maintained in the overlying Bari Shale, Nimbahera Limestone and in the lower parts of the Suket Shale. Finally, all the complex acanthomorphs disappear in the lower part of the Suket Shale, much below the boundary between the Lower Vindhyan and Upper Vindhyan groups (Figs. 3, 4). This distribution pattern of complex acanthomorphs suggests early Ediacaran age for the major parts of the Lower Vindhyan succession. The middle and upper parts of the Suket Shale are represented by dominance of *Lophosphaeridium jansoniusii*, *L. rarum* and various species of *Leiosphaeridia* and *Siphonophycus* along with sporadic occurrence of *Obruchevella delicata*, *O. parva, Vandalosphaeridium reticulatum* and herkomorphs referable to *Cristallinium* and *Dictyotidium.* Complex acanthomorphs are conspicuously absent in this assemblage (Figs. 3, 4). The above assemblage is comparable with the assemblages of the Redkino and Kotlin formations of Late Ediacaran of East European Platform (Sergeev, 2009), suggesting Late Ediacaran age for middle and upper parts of the Suket Shale.

The uppermost part of the Suket Shale is marked by the appearance of *Cristallinium cambriense*, *Cymatiosphaera crameri, C. ovillensis, Dictyotidium birvetense* and *Lophosphaeridium tentativum* in wells CH-A and PL-A (Figs. 3, 4). In the well PL-A, *Asteridium tornatum, A. lanatuan* and *Comasphaeridium* cf. *C. strigosum* appear immediately in the overlying sedimentary rocks of the Kaimur Subgroup and continue to occur in the younger units of the Rewa and Bhander subgroups of the Upper Vindhyan succession (Fig. 4). The presence of above forms is broadly indicative of Early Cambrian age for the uppermost parts of the Suket Shale and the overlying Upper Vindhyan sedimentary rocks. The Precambrian-Cambrian boundary is observed to be present in the uppermost part of the Suket Shale corresponding to first appearance level of *Cristallinium cambriense, Dictyotidium birvetense* and *Lophosphaeridium tentativum* (Figs. 3, 4).

The stratigraphic distributions of complex acanthomorphs in the sedimentary rocks of the Lower Vindhyan Group in the studied three wells indicate that forms, such as *Appendisphaera* aff. *A. anguina, Appendisphaera tabifica, A. tenuis, Gyalosphaeridium multispinulosum* and *A. pulchrum* are the dominant constituents in the lower parts of the Lower Vindhyan succession. Above forms abundantly occur in the Khardeola Formation, along with frequent to common occurrence of other complex acanthomorphs (Figs. 3, 4). This assemblage is referred here to as the *Appendisphaera tabifica-Gyalosphaeridium pulchrum-Appendisphaera tenuis* Assemblage. Forms, such as *Appendisphaera fragilis, A. grandis, Cavaspina acuminata, C. basiconica, Triloboacanthosphaeridium tripartita* and *Schizofusa risoria* also occur sporadically. This assemblage is broadly comparable with the *Appendisphaera barbata* (now *A. tabifica*)-*Alicesphaeridium medusoidum–Gyalosphaeridium pulchrum* Assemblage Zone recognised in the Dey-Dey Mudstone Formation (Ediacaran) of the eastern Officer Basin, Australia (Willman *et al.,* 2006). However, forms such as *Alicesphaeridium medusoidum*, *Echinosphaeridium triangulum*, *Multifronsphaeridium pelorium* and *Tanarium mattoides* are absent in the above assemblage recorded from the Lower Vindhyan Group of the Chambal Valley (Figs. 3, 4).

In the overlying Sawa Sandstone and Palri Shale formations (Sand Subgroup), *Cavaspina basiconica, Schizofusa risoria* and *Triloboacanthosphaeridium tripartita* are the abundant constituents. Forms, such as *Apodastoides verobturatus, Appendisphaera? brevispina, A. fragilis, A. grandis, A. tabifica, Cavaspina acuminata, Archaeoacanthodiacrodium flexispinosum, Chambalasphaeridium guchchaensis, Densisphaera fistulosa, Gyalosphaeridium pulchrum, Tanarium anozos, T. conoideum* and *T. tuberosum* are also very common. The acanthomorphic acritarch association of the above two lithounits is referred here to as the *Cavaspina basiconica-Schizofusa risoria-Triloboacanthosphaeridium tripartita* Assemblage. Acanthomorph taxa, such as *Apodastoides verobturatus, Archaeoacanthodiacrodium flexispinosum, Chambalasphaeridium guchchaensis, Tanarium anazos, T. conoideum* and *Triloboacanthosphaeridium tripartita* show their restricted occurrence within this assemblage. This assemblage is closely comparable with the *Tanarium conoideum-Schizofusa risoria-Variomargosphaeridium lithoschum* Assemblage Zone recognised from the Ungoolya Group (Ediacaran) of the Officer Basin, Australia (Grey, 2005; Willman *et al.,* 2006; Willman and Moczydlowska, 2008, 2011). However, forms such as *Tanarium irregulare, T. mattoides, T. muntense* and *Variomargosphaeridium lithoschum* are not recorded in the above assemblage recorded from the Lower Vindhyan succession of the Chambal Valley (Figs. 3, 4).

The complex acanthomorph species, mentioned above, become less prolific in the succeeding Kalmia Sandstone, Binota Shale, Jiran Sandstone, Bari Shale, and Nimbahera Limestone and in the lower parts of the Suket Shale. However, forms, such as *Ceratosphaeridium glaberosum, Knollisphaeridum triangulum* and *Sinosphaera rupina* appear immediately above the upper boundary of the preceding assemblage within upper parts of Palri Shale and become common in the overlying lithounits of the Kalmia Sandstone, Binota Shale, Jiran Sandstone, Bari Shale, Nimbahera Limestone and in the lower part of the Suket Shale. Forms, such as *Appendisphaera tabifica, Cavaspina acuminata, Densisphaera fistulosa, Gyalosphaeridium pulchrum, Schizofusa risoria* and *Tanarium tuberosum* are very common in this assemblage. This assemblage is referred here as the *Sinosphaera rupina- Densisphaera fistulosa-Ceratosphaeridium glaberosum* Assemblage. It is broadly comparable with the *Tanarium irregulare-Ceratosphaeridium glaberosum-Multifronsphaeridium pelorium* Assemblage Zone recognised from the Ungoolya Group (Ediacaran) of Officer Basin, Australia (Grey, 2005; Willman *et al.,* 2006; Willman and Moczydlowska, 2008, 2011). However, forms such as *Cavaspina amplitudinus, Labruscasphaeridium intertextum, Multifronsphaeridium pelorium* and *Tanarium irregulare* are not recorded in the above assemblage reported from the Lower Vindhyan succession of the Chambal Valley.

Acritarch taxa, such as *Ceratosphaeridium mirabile*, *Distosphaera australica* and *Pennatosphaeridium chrysanthemoides* corresponding to the *Ceratosphaeridium mirabile-Distosphaera australica-Apodastoides verobturatus*

Assemblage Zone of Australia (Grey, 2005; Willman *et al.,* 2006; Willman and Moczydlowska, 2008, 2011), are not recorded from the sedimentary rocks of the Lower Vindhyan Group of Chambal Valley. The *Sinosphaera rupina-Densisphaera fistulosa-Ceratosphaeridium glaberosum* complex acanthomorph assemblage of the Lower Vindhyan Group is succeeded by an acritarch assemblage having abundant occurrence of *Lophosphaeridium rarum, Vandalosphaeridium reticulatum* and large filamentous microfossils (*Obruchevella, Siphonophycus* and *Vandotaenia*) of Late Ediacaran age.

The *Leiosphaeridia, Lophosphaeridium, Vandalosphaeridium* and filamentous microfossils dominated the assemblage of middle and upper parts of the Suket Shale is referred here to as the *Lophosphaeridium rarum-Vandalosphaeridium reticulatum* Assemblage of Late Ediacaran age. This assemblage resembles Late Ediacaran acritarch assemblages recorded from the East European Platform (Volkova, *et al.,* 1983; Burzin, 1990, 1994). The uppermost part of the Suket Shale and the overlying sedimentary rocks of the Kaimur and the Rewa groups in the well PL-A, having common occurrence of *Asteridium lanatum, Comasphaeridium* sp. cf. *C. strigosum, Dictyotidium birvetense, Lophosphaeridium tentativum* and *L. truncatum* are referred here as the *Dictytidium birvetense-Lophosphaeridium tentativum* Assemblage. This assemblage is comparable with the Rovno acritarch assemblages recorded from East European Platform and Lubline Slope, Poland (Volkova *et al.,* 1983; Moczydlowska, 1991, Sergeev, 2009), suggesting basal Early Cambrian age. Sedimentary rocks of the Bhander Subgroup in well PL-A is marked by the appearance of *Cristallinium cambriense, Cristallinium ovillense* and *Cymatiosphaera crameri* along with the presence of forms of the preceding Assemblage. This assemblage is referred here to as the *Asreridium tornatum-Cristallinium cambriense* Assemblage which is comparable with the Early Cambrian acritarch assemblages known from the East European Platform (Volkova *et al.,* 1979, 1983; Moczydlowska, 1991).

Comparison with known Ediacaran complex acanthomorph assemblages

The newly recorded complex acanthomorph assemblages from the subsurface Lower Vindhyan succession of CH-A, SK-A and PL-A wells of the Chambal Valley part of the Vindhyan Basin (Pl. I-VIII) are closely comparable with the known complex acanthomorphic acritach assemblages recorded from the Ediacaran sedimentary rocks that occur above the Varangerian/Elatina glacial layers. It resembles the Ediacaran complex acanthomorph assemblages of the Siberian Platform recorded from the Khamaka Formation (Yakutia), Eastern Siberia (Moczydlowska *et al.,* 1993; Moczydlowska, 2005) and Ura Formation (Baikal-Patom Uplift), Central Siberia (Sergeev *et al.,* 2011; Moczydlowska and Nagovitsin, 2012). Majority of the acanthomorphic acritarch taxa occurring in the Ediacaran successions of the Siberian Platform are recorded from the Lower Vindhyan sedimentary rocks of the Chambal Valley.

The Lower Vindhyan acanthomorph assemblages are also broadly comparable with the Ediacaran (Vendian) acanthomorph assemblages recorded from the East European Platform (Vorob'eva *et al.,* 2009a, 2009b). Taxa, such as *Appendisphaera* aff. *A. anguina*, *Cavaspina acuminata*, *Tanarium conoideum* and *T. tuberosum* are common in both the assemblages. Other acanthomorph taxa recorded from the East European Platform are not recorded in the Lower Vindhyan Group assemblages. In addition, the Chambal Valley ECAP assemblages are also closely comparable with the Doushantuo Formation (Yangtze Gorges, South China) acanthomorph assemblages (Zhang *et al.,* 1998; Liu *et al.,* 2013, Liu *et al.,* 2014; Xiao *et al.,* 2014) as majority of the forms are common in both the areas. The acanthomorphic acritarch assemblage from the Infrakrol sedimentary rocks of Musssoorie Syncline (Lesser Himalaya), India (Tiwari and Knoll, 1994) is also broadly comparable with the present assemblage.

The complex acanthomorph asemblages, earlier recorded from the Pertatataka Formation (Amadeus Basin), Central Australia (Zang and Walter, 1989; 1992; Grey, 2005) and the Dey-Dey Mudstone and Karlaya Limestone (Murnaroo-1 well) succession (eastern Officer Basin) from South Australia (Willman *et al.,* 2006; Willman and Moczydlowska, 2008, 2011) are also comparable with the Chambal Valley assemblage as majority of the acanthomorphs taxa recorded from the eastern Officer Basin abundantly occur in the Lower Vindhyan sedimentary rocks of Chambal Valley.

The resemblance of the Chambal Valley complex acanthomorph assemblages with the known Ediacaran complex acanthomorph assemblages provides strong biostratigraphic evidence of Early Ediacaran age for the Lower Vindhyan sedimentary rocks of the Chambal Valley, which, until now, are dated as Late Paleoproterozoic-Early Mesoproterozoic on the basis of radiometric dating. In the presently studied wells, middle and upper parts of the Suket Shale (uppermost parts of the Lower Vindhyan Group) show the complete absence of complex acanthomorphs as these forms abruptly disappear in the lower part of the Suket Shale (Figs. 3, 4). The middle and upper part of the Suket Shale are marked by the occurrence of abundant sphaeromorphs having granulated ornamentation *(Lophosphaeridium rarum, L. jansoniusii*), various species of *Leiosphaeridia* and *Siphonophycus* along with rare occurrence of *Dictyotidium* sp., *Obruchevella valdaica, O. parva* and *Vandalosphaeridium reticulatum.* The recovered assemblage from the middle and upper parts of the Suket Shale broadly suggests a late Ediacaran age due to abundant occurrence of *Lophosphaeridium,* leiosphaerids and filamentous microfossils and species of *Obruchevella* (Volkova, *et al.,* 1983; Burzin, 1990, 1994; Sergeev, 2009).

The sedimentary rocks of the uppermost Suket Shale (Lower Vindhyan Group) in wells CH-A and PL-A, and the overlying sedimentary rocks of the Kaimur and Rewa subgroups (2550-1485m) in well PL-A recorded acritarchs and other associated organic-walled microfossil assemblages similar to the underlying middle and upper parts of the Suket Shale, along with the occurrence of *Asteridium lanatum, A. tornatum, Comasphaeridium* cf. *C. strigosum, Dictyotidium birvetense, Lophosphaeridium tentativum* and *L. truncatum* (Fig. 4). This assemblage is broadly comparable with the Rovno acritarch assemblage (Volkova, *et al.,* 1983; Moczydlowska, 1991; Sergeev, 2009), suggesting basal Early Cambrian age for the uppermost part of the Suket Shale of the Lower Vindhyan succession and the overlying Kaimur and Rewa subgroups of the Upper Vindhyan succession. The overlying sedimentary rocks from depth-interval 1485-97m in well PL-A (Fig. 4), covering the Bhander Subgroup, recorded the frequent occurrence of *Asteridium lanatum, A. tornatum, Cristallinium cambriense, C. ovillense*, *Cymatiosphaera crameri, Cymatiosphaera* cf. *C. ovillensis, Dictyotidium birvetense* and *Lophosphaeridium truncatum*. This assemblage broadly suggests an Early

Cambrian age approximately corresponding to the Lontova (Tommotian) and Talsy-Lukati and Vergale (Atdabanian) acritarch assemblages (Moczydlowska, 1991; Sergeev, 2009).

Biostratigraphic significance and interpretation

The record of complex acanthomorphic acritarchs from the subsurface Lower Vindhyan sedimentary rocks in wells CH-A, SK-A and PL-A suggests early Ediacaran age for the major parts of the Lower Vindhyan succession of the Chambal Valley (east Rajasthan). Additionally, late Ediacaran to Early Cambrian age for the uppermost Lower Vindhyan Group (middle, upper and uppermost parts of the Suket Shale) has been assigned based on the record of Precambrian-Cambrian transion acritatch assemblages (Figs. 3, 4). The overlying sedimentary rocks of the Kaimur, Rewa and Bhander subgroups of the Upper Vindhyan succession has been assigned the Early Cambrian based on the record of Early Cambrian marker acritarch taxa as mentioned above (Figs. 3, 4). It is worth mentioning that Salujha *et al*. (1971b) recorded the occurrence of marker acritarch taxa of Vendian-Cambrian aspect, such as *Baltisphaeridium, Cristallinium, Cymatiosphaera, Dictyotidium* and *Lophosphaeridium* from the Suket Shale (upper part of the Lower Vindhyan Group) and from the overlying Kaimur, Rewa and Bhander subgroups (Upper Vindhyan Group) in outcrop areas of the Chambal Valley. Salujha *et al*. (1971b) suggested Vendian (Ediacaran) age for the Lower Vindhyan succession and Cambrian-Ordovician age for the Upper Vindhyan succession. However, majority of the workers have questioned their findings as radiometric ages of Late Palaeoproterozoic-Mesoproterozoic for the Lower Vindhyan Group and Late Mesoproterozoic-Neoproterozoic age for the Upper Vindhyan Group were given more weightage. Moreover, majority of the radiometric ages ranging from Late Paleoproterozoic to Late Neoproterozoic (ca 1730-550 Ma) are available from the Son valley part of the Vindhyan Basin. Only few radiometric data are available from the Vindhyan sedimentary rocks of the Chambal valley indicating Late Paleoproterozoic-Early Mesoproterozoic (ca 1700-1600Ma) age for the Lower Vindhyan Group (Ray *et al.,* 2003) and Late Mesoproterozoic to Late Neoproterozoic (ca 1073 Ma to 650 Ma) age for the Upper Vindhyan sedimentary rocks (Srivastava and Rajgopalan, 1988; Ray *et al.,* 2003; Malone *et al.,* 2008).

In the Son Valley part of Vindhyan Basin, Azmi (1998) and Azmi *et al.* (2007) recorded small shelly fossils, animal embryos, calcareous skeleton algae, small acanthomorphic acritarchs, sponge spicules and metaphyte of Precambrian-Cambrian transition aspect from the Lower Vindhyan sedimentary rocks of Rohtas Subgroup (Rohtas Limestone and Bhagwar Shale). Based on their findings, they placed the Precambrian-Cambrian boundary close to the Rohtas Limestone/Bhagwar Shale contact, and assigned Bhagwar Shale and overlying Kaimur, Rewa and Bhander sedimentary rocks (Upper Vindhyan Group) as Early Cambrian. Later on, Bengtson *et al*. (2009) also recorded the similar fossils and confirmed the veracity of fossil records by Azmi and his coworkers (1998, 2007), but assigned Late Paleoproterozoic-Early Mesoproterozoic (ca 1630-1550 Ma) age for the Rohtas Subgroup with the comment that Azmi's findings of Cambrian fossils were real, but more than 1 billion year older.

The present record of characteristic complex acanthomorphic acritarchs of Ediacaran age from the Lower Vindhyan succession of the Chambal Valley offers two interpretations for its age. Firstly, the Lower Vindhyan sedimentary rocks of the Chambal Valley may be of the Ediacaran age, and corroborates the findings of Salujha *et al.* (1971a, 1971b), Azmi (1998), Azmi *et al.* (2007) and Kathal *et al.* (2000) that suggested Ediacaran age for the Lower Vindhyan succession of the Son Valley. The second interpretation could be that these acanthomorphic acritarchs might have evolved much prior to Late Palaeoproterozoic-Early Mesoproterozoic time as ages of various lithounits of the Lower Vindhyan Group of the Son Valley and Chambal Valley are bracketed at ca 1730-1500 Ma by U-Pb and Pb/Pb (Ray *et al.,* 2002, 2003; Ray, 2006; Rasmussen *et al.,* 2002; Sarangi *et al.,* 2004; Malone *et al*., 2008).

Addionally, the records of acanthomorph acritarch *Cymatiosphaeroides kullungii* of Cryogenian aspect from Chitrakoot Formation (Anbarasu, 2001) and helically coiled filamentous microfossils (*Obruchevella parva* and *O. pusilla*) from the Salkhan Limestone by Rai and Singh (2004) from the Lower Vindhyan succession in the Son Valley also support the present inference of Ediacaran age for the Lower Vindhyan Group. It would be rather illogical if the present record of Ediacaran complex acanthomorphs and other earlier fossil records of Ediacaran aspects from the Lower Vindhyan succession, are interpreted against the background of available radiometric age of Late Palaeoproterozoic-Early Mesoproterozoic for the Lower Vindhyan succession.

Thus, the present record of Ediacaran marker acanthomorphic acritarchs from the subsurface sedimentary rocks of the Lower Vindhyan Group of the Chambal valley suggests that initiation of sedimentation in the western parts of the Vindhyan Basin (Chambal Valley) commenced during Late Neoproterozoic (Ediacaran) and terminated during the Early Cambrian. The depositional history of the Vindhyan succession of the Chambal valley appears different from that of the Vindhyan successions of the Son valley and may be representing a separate basin. More biostratigraphic work is required in the Chambal and Son valleys parts of the Vindhyan Basin to augment the present findings and understanding of the depositional history of this basin in the light of present record of complex acanthomorphs of Ediacaran age from the Lower Vindhyan sedimentary rocks of the Chambal valley.

POINTS TO PONDER

The occurrence of characteristic Ediacaran complex acanthomorphs in the subsurface Lower Vindhyan succession of the Chambal Valley is very significant and perplexing. Their occurrence offers two interpretations. Firstly, the Lower Vindhyan Group may be Ediacaran in age corroborating the similar views inferred earlier by some workers on its age. Another interpretation could be that the complex acanthomorphs, previously with known ranges restricted to Ediacaran successions, might have evolved much earlier during Late Palaeoproterozoic-Early Mesoproterozoic time since the Lower Vindhyan succession are radiometrically dated ca 1730-1500 Ma.

Nevertheless, the presence of complex acanthomorphic acritarchs in the Lower Vindhyan succession of the Chambal Valley suggests that sedimentation in this part of the Vindhyan Basin commenced during Ediacaran time and ceased during the Early Cambrian. The Vindhyan succession of the Chambal Valley region appears different from the Vindhyan succession of the Son Valley, and may be representing a separate basin.

SYSTEMATIC PALAEONTOLOGY

The complex acanthomorphic acritarchs recorded from Lower Vindhyan sedimentary rocks in wells CH-A, PL-A and SK-A, drilled in Chambal Valley parts of the Vindhyan Basin (Fig. 1b) are described below in alphabetical order and illustrated through microphotographs in photoplates (Pl. I - VIII). Numbers of specimens measured for dimensions of described taxa are mentioned with symbol "N" in bracket. Stratigraphic ranges of the recorded complex acanthomorphs and other associated acritarchs are shown in Fig. 3 and Fig. 4 with recognised assemblages and their inferred age.

Group **Acritarcha** Evitt, 1963

Subgroup **Acanthomorphitae** Downie, Evitt and Sarjeant, 1963

Genus ***Apodastoides*** Zhang, Yin, Xiao and Knoll, 1998, emend., Grey, 2005

(*Type species*: *Apodastoides basileus* Zhang, Yin, Xiao and Knoll, 1998. Upper Doushantuo Formation, Shipai Section, Terminal Proterozoic, Hubei Province, China)

Apodastoides aff. *A. verobturatus* Grey, 2005
(Pl. I, figs. 1-2)

Comasphaeridium sp. – Gravestock *et al*., 1997, p. 92, fig. A.

Apodastoides verobturatus n. sp. – Grey, 2005, pp. 201–203, figs. 10B, 43B, 82, 83A–E, 84A–E.–Willman *et al.,* 2008, p. 25, pl. I, figs. 1-2.– Willman and Moczydlowska, 2008, p. 519, Fig. 7A.

Material: Eleven specimens from the Khardeola Formation and the Sawa Sandstone (Lower Vindhyan Group) in well CH-A between the depth-interval 1690-1815m and in the lower parts of the undifferentiated Lower Vindhyan Group well PL-A between the depth-interval 3085-3180m.

Description: Vesicle subcircular to oval. Vesicle bears regularly arranged, long, homomorphic processes which are distinctly separated from each others. Processes simple, cylindrical, hollow inside, attached with the vesicle by the basal plugs. Distal portion of the processes slender and flexuous with blunt tips, distal portion of the processes often curved.

Dimensions: Vesicle diameter 54-52µm, process length 8-12µm (N=7).

Remarks: Processes in the specimens referable to *Apodastoides verobturatus* recorded from the Lower Vindhyan succession are shorter, less widely spaced, and over all size of the vecicle is smaller than those reported from the Ediacaran rocks of Officer Basin, Australia (Grey, 2005; Willman *et al.,* 2006; Willman and Moczydlowska, 2008). So, the specimens are referred here as *Apodastoides* aff. *A. verobturatus.*

Genus ***Appendisphaera*** Moczydlowska, Vidal and Rudavskaya, 1993, emend. Moczydlowska, 2005

(*Type species*: *Appendisphaera grandis* Moczydlowska, Vidal and Rudavskaya, 1993, emend. Moczydlowska, 2005. Kursov Formation, Ediacaran, Yakutia, Siberian Platform)

Appendisphaera aff. *A. anguina* Grey, 2005
(Pl. I, figs. 3-4)

Appendisphaera anguina Grey, 2005, p. 206, figs. 88A, 90.

Appendisphaera aff. *A. anguina* Grey, 2005 – Vorob'eva *et al.,* 2009b, p. 168, figs. 9.9, 9.9a.– Liu *et al.,* 2014, p. 11, figs. 5.1A-B, 6.1- 6.8.

Material: Eight specimens from Khardeola Formation (Lower Vindhyan Group) in well CH-A between the depth-interval 1850-1871m and five specimens from lower parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3250-3305m.

Description: Vesicle large to medium size, subcircular to oval, originally sphaerical. Vesicle bears abundant, well-built, long, densely arranged, clearly separated homorphic processes that emerge from the vesicle. Processes cylindrical, highly flexuous, often entangled and twisted, processes slightly swollen at base, with sharp-pointed and truncated tips. Processes freely communicate with the vesicle cavity.

Dimensions: Vesicle diameter 65-105µm, process length 15-28µm (N=6).

Comparison: The Chambal Valley specimens are broadly comparable with the *Appendisphaera anguina* described by Grey (2005) from the Ediacaran sedimentary rocks of Officer Basin, South Australia and from the Doushantuo Formation, South China by Liu *et al.* (2014). However, the Chambal Valley specimens referable to *A. anguina* are relatively smaller in size-range than those recorded from South Australia and South China and processes are also relatively shorter. Hence, the specimens recorded from the Lower Vindhyan Group are only compared with the *Appendisphaera anguina* and refered here as the *Appendisphaera* aff. *A. anguina*.

Apppendisphaera? brevispina Liu, Xiao, Yin, Chen, Zhou and Li, 2014
(Pl. I, figs. 5-6)

Appendisphaera ? *brevispina* Liu *et al.,* 2014, pp.11-12, figs. 5.3, 7.3 - 7.5.

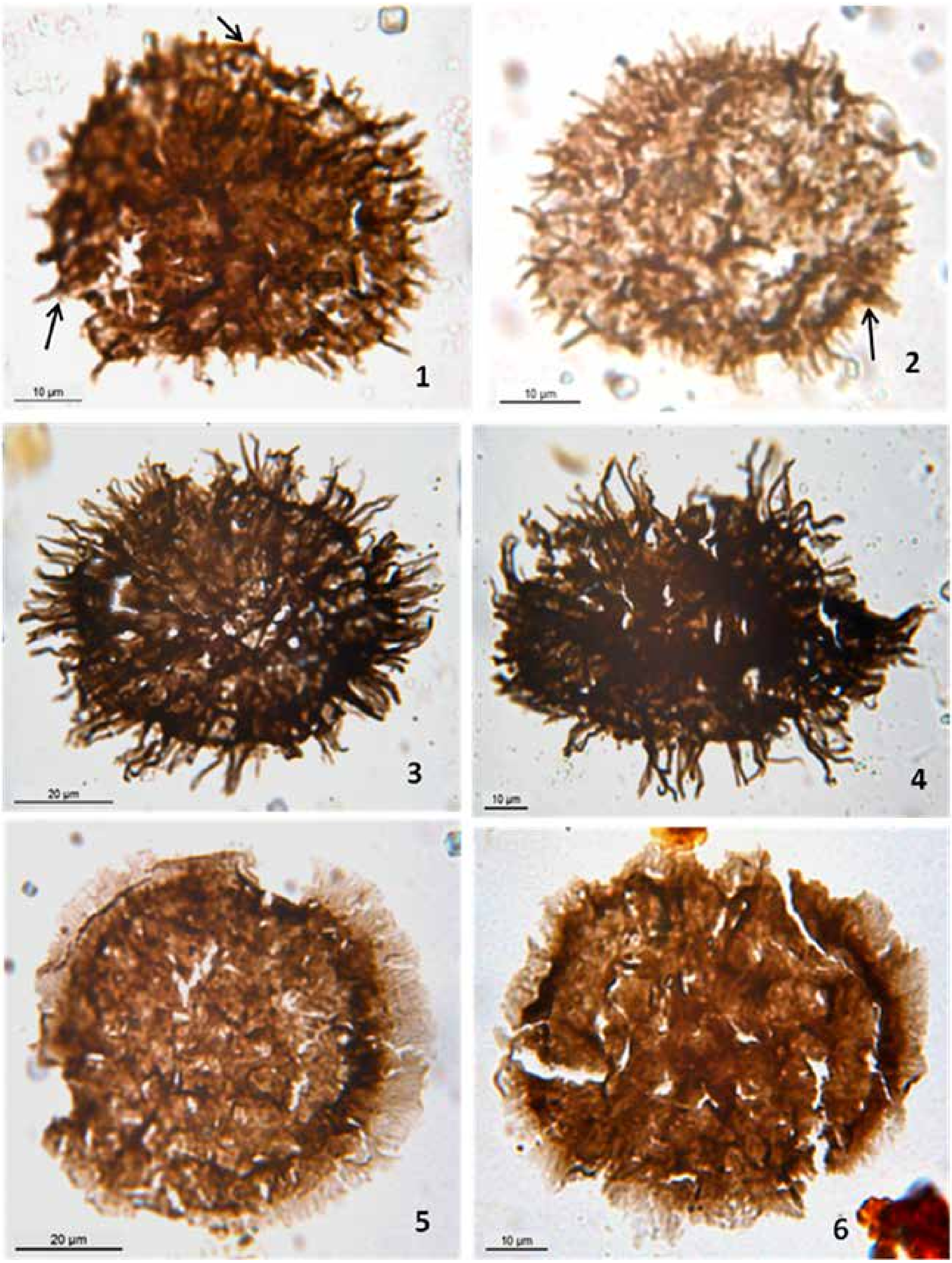
Material: Twelve specimens from Khardeola Formation, Sawa Sandstone and Palri Shale (Lower Vindhyan Group) in well CH-A between depth-interval 1510-1835m and eight specimens from lower parts of the undifferentiated Lower Vindhyan succession in well PL-A between depth-interval 3085-3180m.

Description: Vesicle small to medium size, circular to subcircular, originally sphaerical, vesicle-wall dark and hyaline, with clearly defined vesicle outline. Vesicle bears abundant, densely arranged but clearly separated, regularly distributed, short, homomorphic processes of almost uniform length. Processes are simple, cylindrical, with blunt or truncated tips. Processes often coalesce, forming a frill-like, narrow translucent rim around the vesicle, processes length approximately 10% or less of the vesicle diameter. Processes freely communicate with the vesicle interior.

EXPLANATION OF PLATE I

1. ***Apodastoides*** aff. ***A. verobturatus*** showing regularly distributed, clearly separated, cylindrical processes having dark basal plugs (arrows indicating basal plugs and curved distal portion with blunt tips); well CH-A, depth-int. 1770-75m/1, EF. T57; 2. ***Apodastoides*** aff. ***A. verobturatus*** showing widely distributed, cylindrical processes with curved distal portion and blunt tips (arrow indicating a thickened basal plug) well CH-A, depth-int. 1790-95m/1, EF. T64/4; 3. ***Appendisphaera* aff. *A. anguina*** showing long, flexuous and twisted homomorphic processes; well CH-A, depth-int. 1870-75m/1, EF. D42/4; 4. ***Appendisphaera* aff. *A. anguina*** displaying highly flexuous, twisted and entangled homomorphic processes; well CH-A, depth-int. 1870-75m/1, EF. D31/2; 5. ***Appendisphaera ? brevispina*** showing densely arranged, short, homomorphic, cylindrical processes, coalesced processes displaying a translucent narrow rim around the vesicle, well CH-A, depth-int. 1790-95m/2, EF. M52/4; 6. ***Appendisphaera? brevispina*** displaying short, closedly spaced, homomorphic processes of uniform length, coalesced processes showing a narrow rim around the vesicle; well CH-A, depth-int. 1750-55m/2, EF. X29.

Plate I



Dimensions: Vesicle diameter 56-75µm, process length 5-8µm (N=12).

Comparison: The Chambal Valley specimens referable to *Appendisphaera? brevispina* Liu *et al.* (2014) are morphologically comparable with those recorded from the Doushantuo Formation (South China). However, specimens from the Lower Vindhyan Group differ from *Appendisphaera? brevispina* described by Liu *et al.* (2014) being smaller in size range and in having relatively shorter processes that form a narrow, frill-like outer rim around the vesicle. So, the Chambal Valley specimens are broadly compared with the *Appendisphaera? brevispina* Liu et al. (2014).

Appendisphaera fragilis Moczydlowska, Vidal and Rudavskaya, 1993, emend. Moczydlowska, 2005
(Pl. II, figs. 1-2)

Appendisphaera fragilis n. sp. - Moczydłowska *et al.,* 1993 p. 505, text-fig 6A and B.

Ericiasphaera fragilis (Moczydłowska *et al.,* 1993) comb. nov.- Grey, 2005, figs. 159D and 160B.

Ericiasphaera fragilis (Moczydłowska *et al.* , 1993) comb. nov.- Grey, Non 2005, figs. 159 A–C, E and F and 160A and C.

Appendisphaera fragilis (Moczydłowska *et al.*) – Moczydłowska, 2005, p. 296, fig. 6D.

Material: Sixteen specimens from the Khardeola Formation and Sawa Sandstone (Lower Vindhyan Group) in well CH-A between the depth-interval 1690-1871m and ten specimens from lower parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3250-3305m.

Description: Vesicle large to medium size, subcircular to oval, originally sphaerical. Vesicle bears simple, widely spaced, and evenly distributed, long, homomorphic processes, of almost equal length. Processes are thin, cylindrical, ciliate and fragile, mainly flexuous, with sharp-pointed tips.

Dimensions: Vesicle diameter 100-136µm, processes length 9-12µm (N=15)

Appendisphaera grandis Moczydlowska, Vidal and Rudavskaya, 1993, emend. Moczydlowska, 2005
(Pl. II, figs. 3-4)

Baltisphaeridium (?) *strigosum* Jankauskas – Pyatiletov and Rudavskaya, 1985, p. 152, pl. 63, figs. 7, 9.

Baltisphaeridium strigosum Jankauskas – Rudavskaya and Vasileva, 1989, pl. 1, figs. 2–4; pl. 2, figs. 1–2.

Appendisphaera grandis n. sp. – Moczydłowska, Vidal and Rudavskaya, 1993, pp. 503–505, pl. 1, figs. 1–2, text-fig. 5.

Comasphaeridium magnum Zhang, 1984 –Yuan and Hofmann, 1998, p. 197, fig. 6A–B.

Appendisphaera grandis Moczydłowska *et al.,* 1993 emended – Moczydłowska, 2005, pp. 294–296, fig. 3A–D, fig. 4A–F.

Appendisphaera grandis Moczydłowska, Vidal and Rudavskaya, 2006 – Knoll *et al*., fig. 3g. – Willman and Moczydłowska, 2008, pp. 519-520, fig. 6C. – Chen *et al.,* 2010, fig. 2.1. – Golubkova *et al.,* 2010, pl. 1, fig. 1, pl. 3, figs. 4, 10. – Xiao *et al.,* 2014, p. 9, figs. 3. 1-3.

Material: Twenty five specimens from Khardeola Formation, Sawa Sandstone and Palri Shale (Lower Vindhyan Group) in well CH-A between the depth-interval 1510-1845m and eleven specimens from lower parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3085-3305m.

Description: Vesicle circular to subcircular, originally sphaerical. Vesicle bears abundant, densely arranged, but clearly separated from each other, evenly distributed, long, cylindrical processes of almost equal length. Processes are simple, long, homomorphic, distally become slender and thin, taper into sharp-pointed tips. Processes hollow and freely communicate with the vesicle cavity.

Dimensions: Vesicle diameter 50-80µm, process length 9-12µm (N=10).

Remarks: Specimens of *A. grandis* recorded from the Lower Vindhyan Group of Chambal Valley (east Rajasthan) are relatively smaller in size range than those recorded from the Siberian Platform, Australia and China.

Apppendisphaera tabifica Moczydlowska, Vidal and Rudavskaya, 1993, emend. Moczydlowska, 2005
(Pl. II, figs. 5-6; Pl. III, figs. 1-2)

Pro parte Cymatiosphaeroides dilutopilum n. sp. – Zang *in* Zang and Walter, 1992a, p. 36, fig. 32D–F.

Pro parte Cymatiosphaeroides dilatopilum n. sp. – Zang *in* Zang and Walter, 1992a, p. 36, fig. 32A–C.

Pro parte Comasphaeridium sp. B. – Zang *in* Zang and Walter, 1992 p. 34, fig. 28G.

Appendisphaera? *tabifica* n. sp. – Moczydłowska *et al*., 1993, p. 508, text-fig. 6C–D.

Comasphaeridium sp. – Gravestock *et al*., 1997 p. 91, fig. B.

Appendisphaera barbata n. sp. – Grey, 2005, pp. 209–213, figs. 10C, 88B, 92A–G. – Willman *et al.,* 2006, p. 25.

gen. et sp. indet. – Golubkova and Raevskaya, 2007, pl. I:1–3.

Appendisphaera tabifica - Willman and Moczydłowska, 2008, p. 520, figs. 6D-F, 8C-D.

"*Appendisphaera*" *tabifica* – Golobkova *et al.,* 2010, pl. 1: 5-6.

Appendisphaera tabifica – Moczydłowska and Nagovitsin, 2012, p. 11, figs. 4A –B.

Appendisphaera barbata ? – Liu *et al.,* 2014, p. 11, figs. 5.2, 7.1, 7.2.

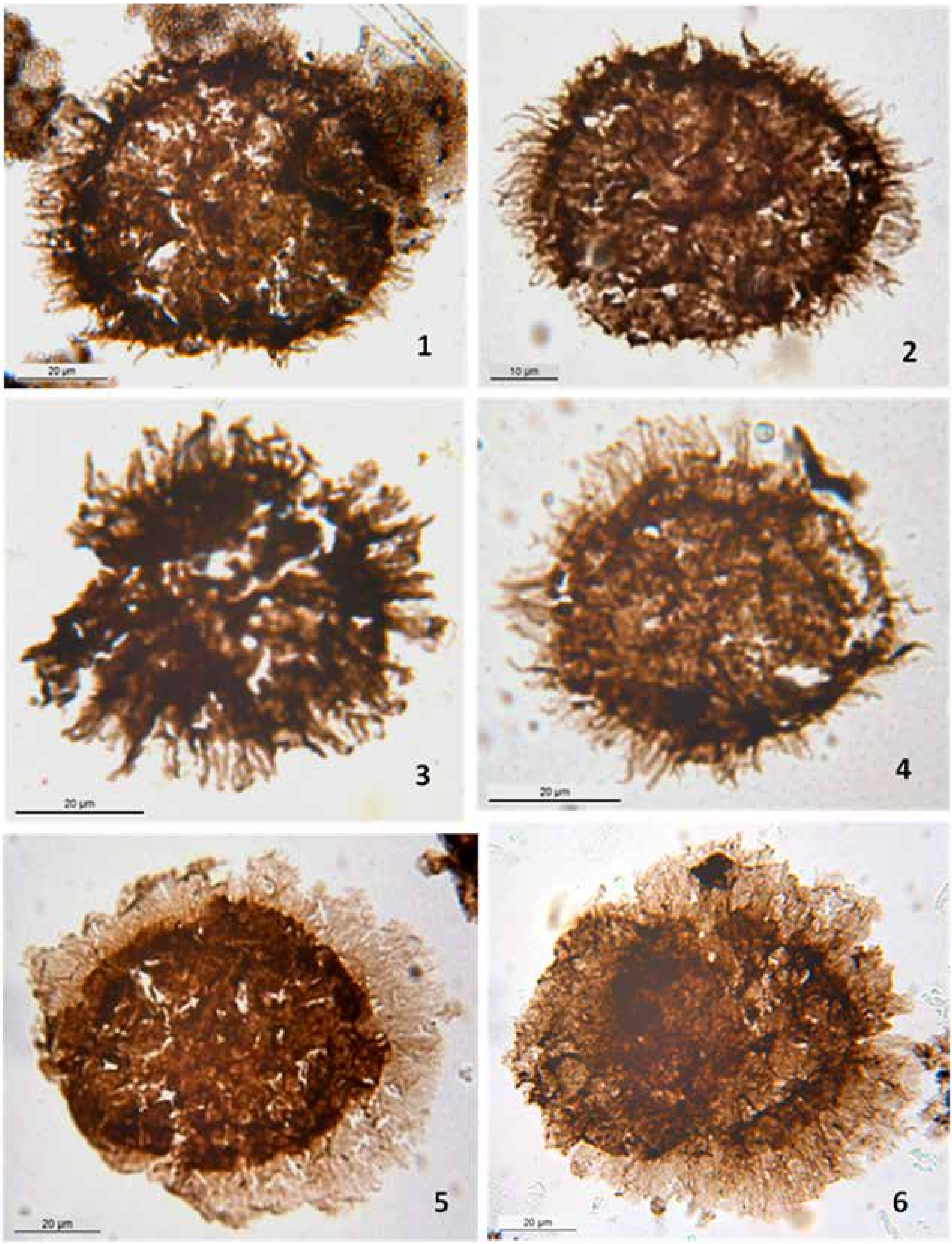
Material: More than sixty specimens are recorded from sedimentary rocks of the Lower Vindhyan Group in well CH-A between the depth-interval 462-1871m and thirty six specimens from the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 2750-3305m.

Remarks: In Chambal Valley assemblages, large number of taxa (more than 100) are recorded with dense central body, having closely spaced, hair-like, coalesced processes over the vesicle. The process to vesicle diameter ratio in some specimens falls between 25% to 30%, where as 15% to 20% in the other case. Forms with process to vesicle diameter ratio between 25% to 30% are placed by Grey (2005) as *A. tabifica* Moczydlowska *et al*. (1993), whereas those having process to vesicle diameter ratio of 15% to 20% into the new species *A. barbata* Grey (2005).

EXPLANATION OF PLATE II

1. ***Appendisphaera fragilis*** showing ciliate and fragile homomorphic processes, with sharp-pointed tips; well PL-A, depth-int. 3085-90m/2, EF. R61/4; 2. ***Appendisphaera fragilis*** showing thin and ciliate cylindrical processes; well CH-A, depth-int. 1790-95m/1, EF. O49/3; 3. ***Appendisphaera grandis*** showing long, densely arranged, simple, homomorphic, cylindrical processes; well CH-A, 1870-75m/2, EF. R25; 4. ***Appendisphaera grandis*** displaying densely arranged, long, homomorphic processes, with sharp-pointed tips; well CH-A, depth-int. 1790-95m/2, EF. X41/1; 5. ***Appendisphaera tabifica*** showing long, closely spaced, hair-like, thin and flexuous processes; well CH-A, depth-int. 1790-95m/1, EF. K33/1; 6. ***Appendisphaera tabifica*** showing long, densely arranged, hair-like, homomorphic flexuous processes; well CH-A, depth-int. 1810-15m/2, EF. L63/1.

Plate II



Authors adopted the views of Willman and Moczydłowska (2008) who have merged the *A. barbata* into *A. tabifica* treating the *A. barbata* as the junior synonym of *A. tabifica* as the ratio between processes to vesicle diameter overlapped, and a number of intermediate forms in between the two species were also recorded by them. In the Lower Vindhyan Group assemblages, numbers of specimens are also observed, having the overlapping ratio of process to vesicle diameter as mentioned above. Thus, the forms recorded from the Lower Vindhyan Group having the process to vesicle diameter ratio ranging from 15% to 30% are assigned here as *A. tabifica* (Moczydlowska, Vidal and Rudavskaya, 1993) emend. Moczydlowska, 2005.

Description: Vesicle medium to large, circular to subcircular, with well defined central body. Vesicle bears densely arranged, long, hair-like, highly flexuous, homomorphic processes. Processes are cylindrical, hollow, with sharp-pointed tips. Processes often coalesced, giving the appearance of translucent outer membranous zone around the vesicle.

Dimensions: Vesicle diameter 95-130µm, process length 15-25µm (N=15).

Apppendisphaera tenuis Moczydlowska, Vidal and Rudavskaya, 1993, emend. Moczydlowska, 2005
(Pl. III, figs. 3-6)

Appendisphaera tenuis n. sp. – Moczydłowska, Vidal and Rudavskaya, 1993, pp. 506–508, text-Fig. 7.

Ericiasphaera spjeldnaesii Vidal, 1990 – Zhang, Yin, Xiao and Knoll, *non*-1998 pp. 26–28.

Appendisphaera tenuis (Moczydłowska *et al*., 1993, emended) – Moczydłowska, 2005, pp. 296–298, fig. 5A–F.

Appendisphaera tenuis – Grey, 2005, pp. 224–226, fig. 113B. – Yin, Zhu, Knoll, Yuan, Zhang and Hu, 2007, p. 661, fig. 1b – Willman and Moczydłowska, 2008, pp. 520-521, figs. 7B-C, 8A-B. – Vorobeva *et al.,* 2008, fig. 2k-2l. – Golubkova *et al.,* 2010, pl.1, fig. 2, pl. 3, figs. 5, 6. – Sergeev *et al.,* 2011, figs. 5.4, 5.6 – Xiao *et al.,* 2014, pp. 9-10, fig. 3. 4. Liu *et al.,* 2014, p. 31, figs. 5. 10, 23. 1-4.

Material: More than forty specimens from Khardeola Formation, Sawa Sandstone and Palri Shale (Lower Vindhyan Group) in well CH-A between the depth-interval 1690-1871m and more than thirty specimens from lower parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3065-3305m.

Description: Vesicle subcircular to oval, originally sphaerical, vesicle wall thick and hyaline. Vesicle bears densely arranged, regularly distributed, short, homorphic processes. Processes are simple, cylindrical, with sharp-pointed tips. Processes freely communicate with the vesicle interior.

Comparison: The Chambal valley specimens resemble with the specimens of *A. tenuis* described by Moczydlowska *et al.* (1993) and Moczydlowska (2005) from the Siberian Platform. However, the Chambal valley specimens are relatively smaller in size than those recorded from Siberian Platform and Australia.

Dimensions: Vesicle diameter 50-80µm; processes lenght 5-8µm (N = 8).

Genus ***Archaeoacanthodiacrodium*** n. gen.

(*Type species: Archaeoacanthodiacrodium flexispinosum,* n. gen. et sp., well CH-A, Khardeola Formation, Lower Vindhyan Group, Chambal Valley, Vindhyan Basin, east Rajasthan, India)

Generic diagnosis: Vesicle medium to small size, transversely oval to elliptic, vesicle-wall thick and hyaline. Development of processes is restricted at the two lateral poles (hemispheres) of the vesicle only. Central part of the vesicle is without the development of processes. Processes on both the lateral poles (hemispheres) are simple, homomorphic, cylindrical with swollen bases and sharp-pointed tips.

Derivation of name : *Archaeo* means old. In regard to being recognised in the older Proterozoic sedimentary rocks in contrast to the similar forms occurring in Early Paleozoic successions, and having the restricted development of processes at two (di) lateral poles (hemispheres) of the vesicle only.

Comparison: The new genus *Archaeoacanthodiacrodium* differs from known complex acanthomorphs in having the restricted development of processes at two lateral poles (hemispheres) of the vesicle only, and central part of the vesicle being hyaline and without development of processes. *Crinita* Vorob'eva *et al.* (2009b) differs from *Archaeoacanthodiacrodium* n. gen. in having processes which are restricted to one hemisphere of the vesicle only, and the processes are much longer than those in *Archaeoacanthodiacrodium. Ancorosphaeridium* (Sergeev *et al.*, 2011) emend. Moczydlowska and Nagovitsin (2012) also differs from the present new genus in having the development of processes over the entire vesicle. Processes in *Ancorosphaeridium* are very long that terminated by grapnel hook-like branches at distal ends. The new genus *Archaeoacanthodiacrodium* has the concentration of processes at both the hemispheres of the vesicle and the central portion of the vesicle is conspicuously without development of processes.

Archaeoacanthodiacrodium flexispinosum n. sp.
(Pl. IV, figs. 1-4)

Holotype: *Archaeoacanthodicroidium flexispinosum* n. sp., Pl. IV, fig.1, well CH-A, depth-int.1790-95m, slide no. 2; microscope coord. 102.5x66.5 (EF. O67/4).

Paratype: *Archaoacanthodiacrodium flexispinosum* new species. Pl. IV, Fig. 4, well CH-A, depth-int.1790-95m, slide no. 1; microscope coord. 100x56 (EF. Q57/3).

Derivation of name: Named after flexuous processes on the two lateral hemispheres (poles) of the vesicle.

Locus typicus: Well CH-A, depth-int. 1790-95m, Khardeola Formation, Lower Vindhyan Group, Chambal valley, Vindhyan Basin, India.

Stratum typicus: Shale and siltstone sedimentary rocks in well CH-A, depth-int. 1790-95m, Khardeola Formation, Lower Vindhyan Group, Chambal valley, Vindhyan Basin, India.

Diagnosis and descriptions: Vesicle medium to small in size, transversely oval to elliptic in shape, vesicle-wall thick

EXPLANATION OF PLATE III

1. ***Appendisphaera tabifica*** displaying densely arranged, hair-like, flexuous, homomorphic processes, coalesced to form a thin translucent layer around the vesicle; well PL-A, depth-int. 3125-30m/1, EF. R 35/2; 2. ***Appendisphaera tabifica*** showing densely arranged, hair-like processes; well CH-A, depth-int. 1750-55m/1, EF. Y52/1; 3. ***Appendisphaera tenuis*** showing, short, densely arranged, cylindrical processes, with sharp-pointed tips; well CH-A, depth-int.1810-15m/2, EF. X47/4; 4. ***Appendisphaera tenuis*** displaying densely arranged, short, homomorphic processes; well CH-A, depth-int. 1810-15m/2, EF. O46/1; 5. ***Appendisphaera tenuis*** showing, short, closely spaced, cylindrical processes; well CH-A, depth-int.1810-15m/1, EF. K58; 6. ***Appendisphaera tenuis*** showing closely arranged, short, homomorphic processes, with sharp-pointed tips; well CH-A, depth-int. 1810-15m/2, EF. K45.

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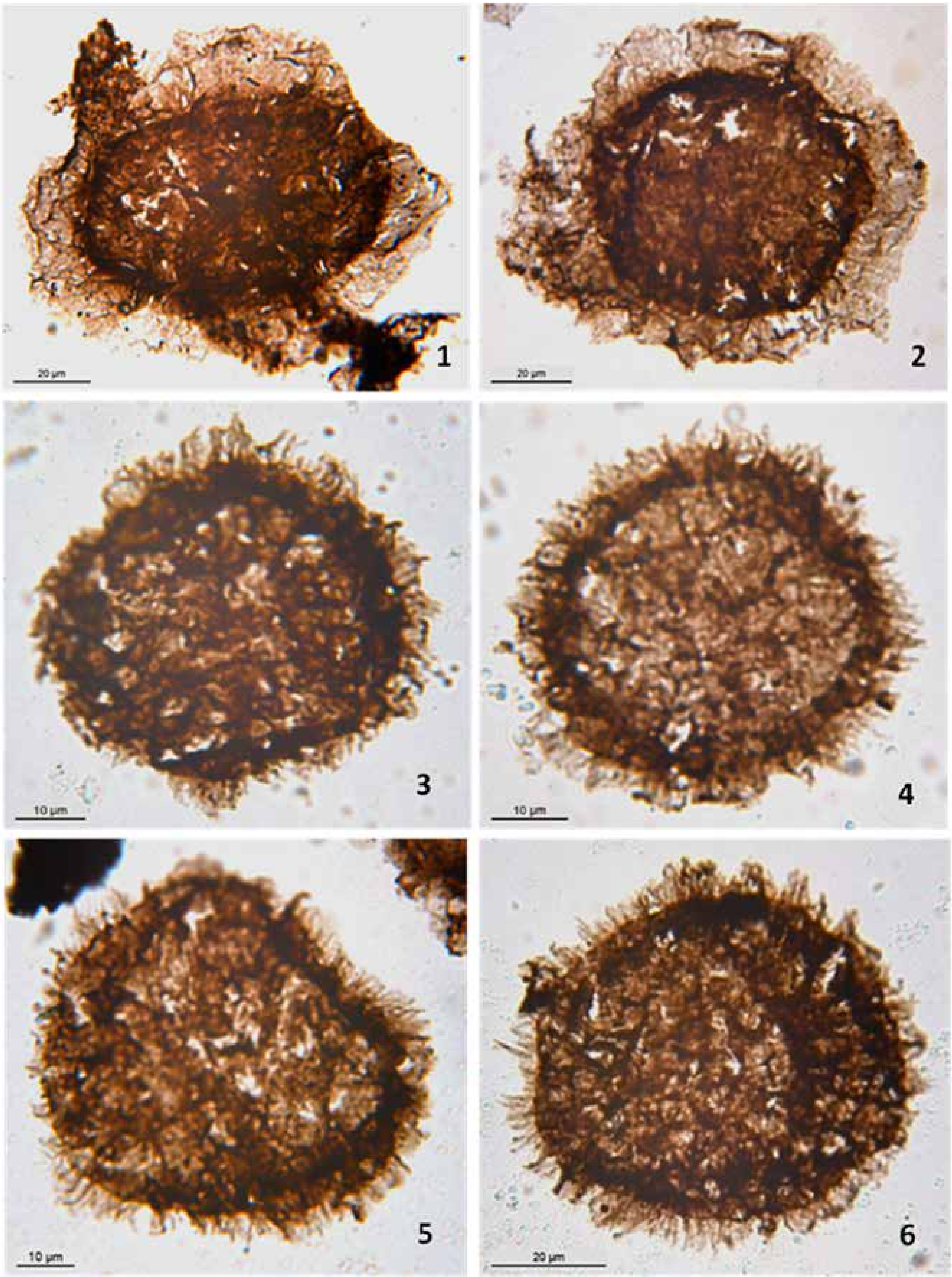
Plate III



and hyaline. Development of processes restricted at two lateral hemispheres (poles) of the vesicle only. Processes at both the hemispheres are simple, homomorphic, densely arranged and evenly distributed. Processes cylindrical, having swollen bulbous base, become slender and flexuous at distal portion, with sharp-pointed tips. Processes hollow and freely communicate with the vesicle cavity. Central portion of the vesicle is without the development of processes.

Material: Eleven specimens from Khardeola Formation, Sawa Sanstone and Palri Shale (Lower Vindhyan Group) in well CH-A between the depth-interval 1690-1795m and eight specimens from lower parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3085-3180m.

Dimensions: Vesicle transverse breadth 45-75µm, longitudinal length 20-37µm, processes length 9-11µm (N=5).

Genus ***Cavaspina*** Moczydlowska, Vidal and Rudavskaya, 1993

(*Type species*: *Cavaspina acuminata* (Kolosova, 1991) Moczydlowska, Vidal and Rudavskaya, 1993. Torgo G-2 drillhole, Torgo Formation, Ediacaran, Yakutia, Siberian Platform)

Cavaspina acuminata (Kolosova, 1991) Moczydlowska, Vidal and Rudavskaya, 1993
(Pl. IV, figs. 5-6)

Baltisphaeridium (?) *strigosum* Jankauskas – Pyatiletov, 1980, p. 11, pl. 1, figs. 5–8, pl. 2, figs. 1–4.

Baltisphaeridium (?) *strigosum* Jankauskas, 1976 – Pyatiletov and Rudavskaya, 1985, p. 152, pl. 63, fig. 8.

Baltisphaeridium strigosum Iank. – Rudavskaya and Vasileva, 1989, pl. 1, figs. 2, 3, 4, 6; pl. 2, figs. 1–2.

Tanarium perfectum Kolosova – Kolosova, 1991, fig. 6:1–6 (*Nomen nudum*).

Comasphaeridium sp. B – Zang and Walter, 1992, p. 34, fig. 28F, G (*Pro parte*).

Cavaspina basiconica n. sp. – Moczydłowska, Vidal and Rudavskaya, 1993 , p. 510–512, text-fig. 11.

Meghystrichosphaeridium perfectum (Kolosova) new combination – Zhang, Yin, Xiao and Knoll, 1998, p. 36, figs. 10.7, 10.8. (invalid)

Cavaspina acuminata (Kolosova, 1991) – Nogovitsin *et al.,* 2004, p. 12, pl. II, figs. 7, 8.

Cavaspina basiconica (Moczydłowska *et al*., 1993) – Moczydłowska, 2005, pp. 300-301, fig. 6C.

"*Vidalia multispinulosa*" – Moczydłowska, 2005, p. 300 (*Nomen nudum*).

Gyalosphaeridium basiconicum (Kolosova, 1991) Moczydłowska *et al.,* 1993) comb. nov. – Grey, 2005, p. 277.

Cavaspina acuminata (Kolosova) emend. Moczydlovska – (sic! Moczydłowska); Veis *et al.,* 2006, pl. I: 5-6, pl. II:1. –Vorobeva *et al.,* 2007, pl. I.E. –Willman and Moczydłowska, 2008, p. 522, fig. 9C. –Vorobeva *et al.,* 2009, p. 177, fig. 7:11 –Willman and Moczydłowska, 2011, pl. II, fig. 3.

Cavaspina cf. *C. acuminata* – Sergeev *et al.,* Non 2011, p. 1003, fig. 10.2.

Cavaspina acuminata (Kolosova, 1991). Moczydłowska *et al.,* 1993 –Moczydłowska and Nagovitsin, 2012 pp. 13-14, fig. 4C-F. – Xiao *et al.,* 2014, p. 16, fig. 7.1-7.6. – Liu *et al.,* 2014, p. 44, fig. 27.1-27.2.

Material: Twenty specimens from sedimentary rocks of the Lower Vindhyan Group in well CH-A between the depth-interval 810-1795m and fifteen specimens from lower and middle parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 2750-3305m.

Description: Vesicle small to medium size, circular to subcircular, vesicle-wall thin and hyaline. Vesicle bears simple, widely spaced, unevenly distributed, short, heteromorphic processes. Processes are predominantly cylindrical with broad bases and sharp-pointed to blunt tips. Distal ends in some processes slightly curved. Processes freely communicate with the vesicle cavity.

Dimensions: Vesicle diameter 35-55µm, processes length 5-6µm (N = 8).

Cavaspina basiconica Moczydlowska, Vidal and Rudavskaya, 1993, emend. Moczydlowska, 2005
(Pl. IV, figs. 7-8)

Baltisphaeridium (?) *strigosum* Jankauskas - Pyatiletov, 1980, p. 11, pl. 1, Figs. 5–8, pl. 2, figs.1–4.

Baltisphaeridium (?) *strigosum* Jankauskas, 1976 - Pyatiletov and Rudavskaya, 1985, p. 152, pl. 63, fig. 8.

Baltisphaeridium strigosum Iank.—Rudavskaya and Vasileva, 1989, pl. 1, figs. 2–4, 6; pl. 2, figs. 1, 2.

Tanarium perfectum (Kolosova) - Kolosova, 1991, fig. 6:1–6 (*Nomen nudum*).

Pro parte 1992b *Comasphaeridium* sp. B – (Zang and Walter), p. 34, fig. 28F, 28G.

Cavaspina basiconica n. sp.—Moczydłowska *et al.,* 1993, p. 510–512, text-fig 11.

Meghystrichosphaeridium perfectum (Kolosova) new combination – Zhang *et al.,* 1998, p. 36, fig. 10.7, 10.8 (invalid).

Cavaspina basiconica (Moczydłowska *et al.,* 1993) – comb. nov. – Moczydłowska, 2005, pp. 300-301, fig. 6C.

"*Vidalia multispinulosa*" – Moczydłowska, 2005, p. 300 (*Nomen nudum*).

Gyalosphaeridium basiconicum (Moczydłowska, Vidal and Rudavskaya, 1993) comb. nov. – Grey, 2005, p.277.

Gyalosphaeridium multispinulosum n. sp. – Grey, 2005, pp. 273-277, figs. 11I, 44I, 179A-D, 180A-E, 181-184.

Cavaspina basiconica (Kolosova, 1991) Moczydłowska, Vidal and Rudavskaya, 1993 – Willman *et al.,* 2006, pp. 26–27, pl. I, figs. 3–4.

Cavaspina basiconica (Kolosova, 1991) Moczydłowska, Vidal and Rudavskaya, 1993 – Willman and Moczydłowska, 2008, pp. 522-523, fig. 9D–F.

EXPLANATION OF PLATE IV

1. ***Archaeoacanthodiacrodium flexispinosum*** (holotype), showing transversely oval vesicle and restricted development of homomorphic cylindrical processes at both the hemispheres of the vesicle, and the median portion without processes; well CH-A, depth-int. 1790-95m/2, EF. O67/4; 2. ***Archaeoacanthodiacrodium flexispinosum*** showing restricted development of homomorphic cylindrical processes at two lateral hemispheres and processes showing bulbous bases and sharp pointed tips (arrow indicating a process with bulbous base); well CH-A, depth-int. 1790-95m/2, EF. Y48/2; 3. ***Archaeoacanthodiacrodium flexispinosum***, showing concentration of homomorphic processes at two lateral poles (hemispheres) only; well CH-A, depth-int. 1710-15m/1, EF. R57/3; 4. ***Archaeoacanthodiacrodium flexispinosum*** (paratype), showing concentration of homomorphic cylindrical processes at two lateral hemispheres only (arrow indicating a process with bulbous base and sharp pointed tips); well CH-A, depth-int. 1790-95m/1, EF. Q 57/3; 5. ***Cavaspina acuminata*** displaying simple, widely distributed, thorn-like, conical processes; well PL-A, depth-int. 3150-55m/1, EF. G29; 6. ***Cavaspina acuminata*** showing few, widely distributed, short, thorn-like, conical processes; well PL-A, depth-int. 2875-80m/1, EF.M47/1; 7. ***Cavaspina basiconica,*** displaying short, cylindrical processes with bulbous bases and sharp-pointed tips; well PL-A, depth-int. 3150-55m/1, EF. O70/2; 8. ***Cavaspina basiconica*** showing short, cylindrical processes with bulbous bases and sharp-pointed tips; well SK-A, depth-int. 1550-55m/1, EF M54; 9. ***Ceratosphaeridium glaberosum*** showing oval vesicle, with a prominant long cylindrical process with sharp-pointed tip; well CH-A, depth-int. 1040-45m/1, EF O66/3; 10. *Ceratosphaeridium glaberosum* showing polygonal vesicle and a prominent, long process with blunt tip; well PL-A, depth-int. 2750-55m/2, EF O46.

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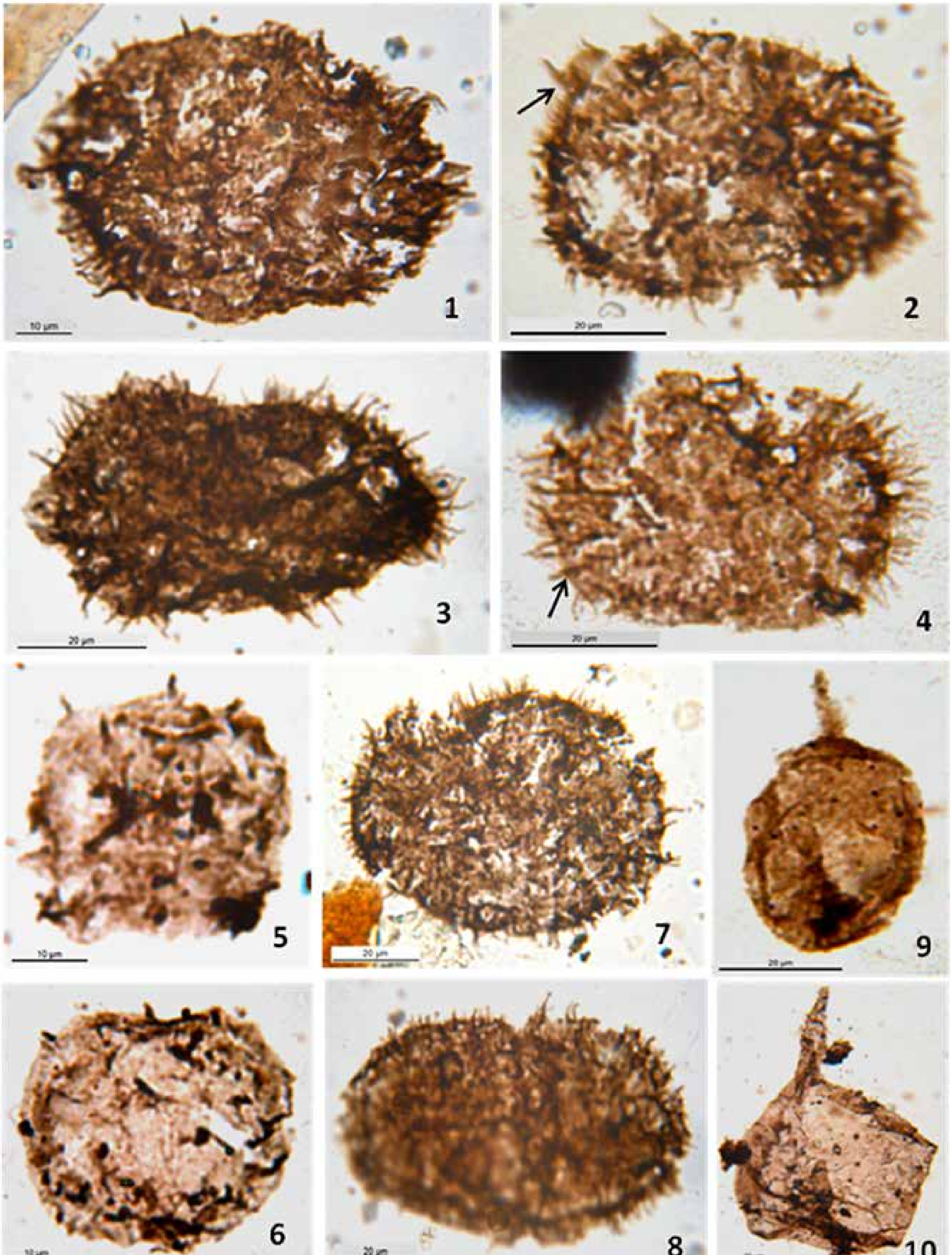
Plate IV



Cavaspina basiconica (Kolosova, 1991) Moczydłowska, Vidal and Rudavskaya, 1993 – Willman and Moczydłowska, 2011, p 25, pl. 2, figs. 1, 2.

Cavaspina basiconica (Kolosova, 1991) Moczydłowska, Vidal and Rudavskaya, 1993 – Xiao *et al.,* 2014, pp. 16-17, fig. 8.1– 8.8.

Cavaspina basiconica (Kolosova, 1991) Moczydłowska, Vidal and Rudavskaya, 1993 – Liu *et al.,* 2014, p. 44, fig. 27.3 – 27.6.

Material: Thirty specimens from Khardeola Formation, Sawa Sanstone and Palri Shale (Lower Vindhyan Group) in well CH-A between the depth-interval 1510-1871m and seventeen specimens from lower parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3085-3305m.

Description: Vesicle subcircular to oval, originally sphaerical. Vesicle wall thin and hyaline, bears abundant, densely arranged, heteromorphic, short processes. Processes are mainly cylindrical, with swollen bulbous bases, often flexuous, distal distally become thin and slender, with sharp-pointed-tips, and rarely conical processes are also present with blunt tips. Processes are hollow and communicate freely with the vesicle cavity.

Dimensions: Vesicle diameter 60-70µm, processes length 6-8µm (N=12).

Genus ***Ceratosphaeridium*** Grey, 2005

(*Type species*: *Ceratosphaeridium mirabile* Grey, 2005; Wilari Dolomite Member, Tanana Formation (middle Ungoolya Group), Ediacaran, Observatory Hill 1 drillhole, Officer Basin, Australia).

Ceratosphaeridium glaberosum Grey, 2005
(Pl. IV, figs. 9-10)

"Acritarch with a prominent process"- Zang in Gravestock *et al*., 1997, p. 90, photo B.

Ceratosphaeridium glaberosum n. sp. - Grey, 2005, pp. 237–241, figs. 134A–F, 135A–G. - Willman *et al*., 2006, p. 27, pl. II, 1–2. -Willman and Moczydłowska, 2008, p. 508, fig. 5C–D.

Ceratosphaeridium cf. *C. glaberosum* Grey – Golubkova *et al*., 2010, pl. IV, fig. 1 (non 2010).

Ceratosphaeridium glaberosum Grey, 2005 – Willman and Moczydłowska, 2011, p. 25, pl. II, fig. 4.

Ceratosphaeridium cf. *C. glaberosum* Grey, 2005 – Moczydłowska and Nagovitsin, 2012, p. 14, Fig. 4D.

Material: Twenty one specimens from sedimentary rocks of the Lower Vindhyan Group in well CH-A between the depth-interval 665-1795m and thirteen specimens from middle and upper parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 2750-3035m.

Description: Vesicle medium to small size, oval to polygonal in shape, vesicle-wall thin and smooth. Vesicle bears a prominent, simple, long, cylindrical process, having wide conical base and blunt to sharp-pointed tip. Process diameter wide, hollow inside and freely communicates with the vesicle cavity.

Dimensions: Vesicle diameter 45-80µm, process length 20-35µm, process width 7-8 µm (N = 4).

Genus ***Chambalasphaeridium*** n. gen.

(*Type species*: *Chambalasphaeridium guchchaensis* n. gen. et sp., well CH-A, Khardeola Formation, Lower Vindhyan Group, Chambal Valley, Vindhyan Basin, east Rajasthan, India)

Derivation of name: The new genus is named after the River Chambal which flows across the Chambal Valley, cutting across the Vindhyan sedimentary rocks in east Rajasthan (India) from where this new genus is being first recorded.

Diagnosis: Vesicle medium to large size, subcircular to oval, vesicle-wall thick and hyaline. Vesicle bears simple, homomorphic processes that emerge from the vesicle in bunches or clusters of three, four or even more, rarely single process emerges from the vesicle. Individual process in the clusters is cylindrical, thin, and distally flexuous, with sharp-pointed tips. Each bunch/cluster of the processes clearly separated from the adjacent clusters. Base of processes in the individual cluster attached with the vesicle through a distinct dark and thickened basal plug.

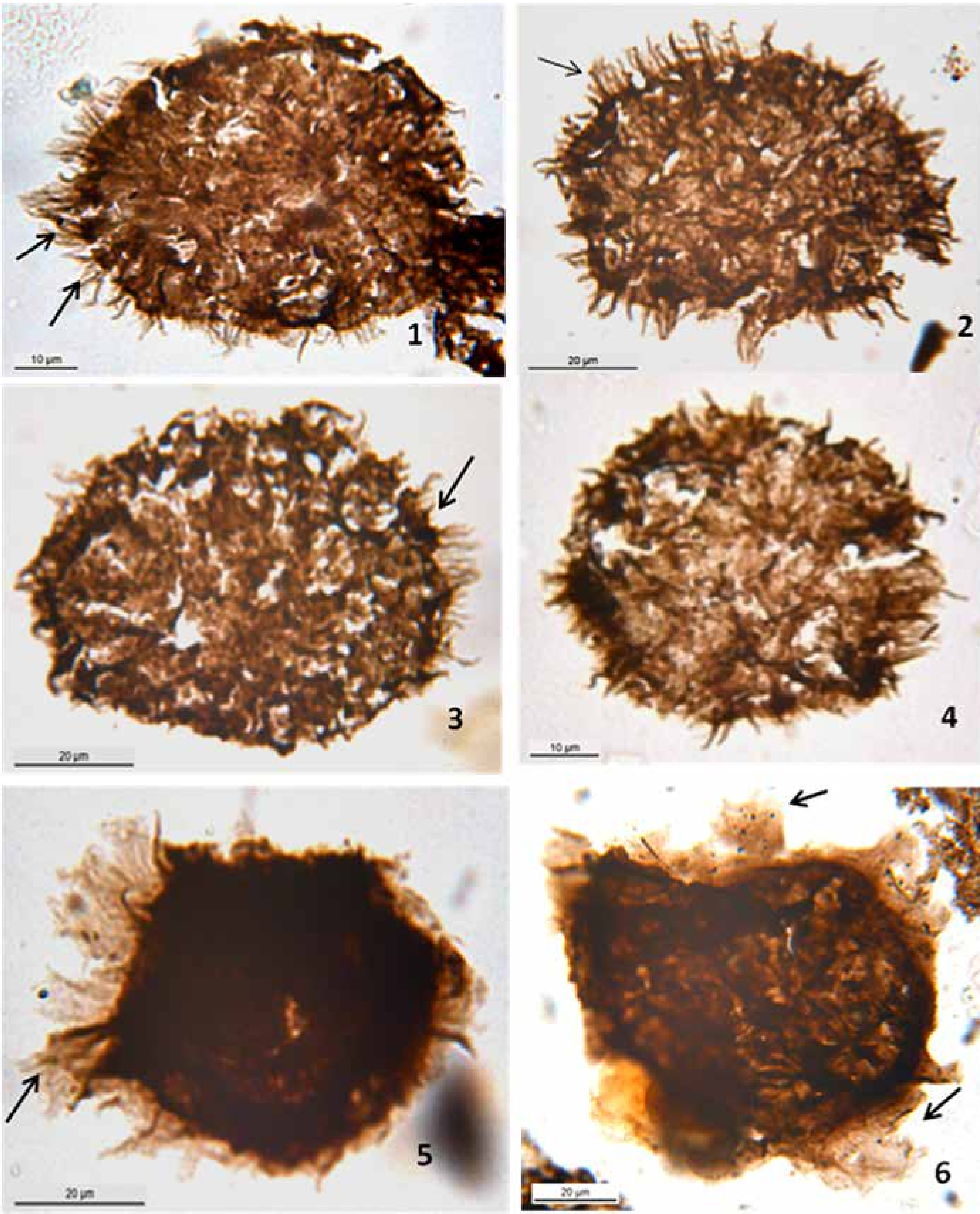
Material: Twelve specimens from Khardeola Formation and Sawa Sandstone (Lower Vindhyan Group) in well CH-A between the depth-interval 1690-1795m and eleven specimens from lower parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3085-3180m.

Comparison: The new genus *Chambalasphaeridium* is distinguishable from the known complex acanthomorphic acritarchs in having processes that emerge from the vesicle in bunches or clusters of three, four or even more. Additionally, the bases of the processes in the individual bunch/cluster are attached with the vesicle through a distinct dark and thickened basal plug. *Tianzhushanaia* Yin, L. and Li (1978) emend. Yin, L., Zhou and Yuan (2008) is broadly comparable with the new genus *Chambalasphaeridium* in having processes that emerge from the vesicle in bunches or clusters. However, *Tianzhushanaia* differs from *Chambalasphaeridium* in having the multilaminate layers surrounding the vesicle-wall and outer membranous layer is supported by the processes and being exceptionally larger in size (370-670µm) than *Chambalasphaeridium*. Multilaminated layers surounding the vesicle-wall and outer membranous layer supported by processes are conspicuousely absent in *Chambalasphaeridium* n. gen.

EXPLANATION OF PLATE V

1. ***Chambalasphaeridium guchchaensis*** (paratype), showing oval vesicle, with long, flexuous, homomorphic processes emerging from the vesicle in bunches of 3 to 5 or more, and attachment of processes with the vesicle through the distinct basal plugs (arrows showing clusters of processes and thickened basal plugs) ; well CH-A, depth-int. 1790-95m/1; EF. R58/1; 2. ***Chambalasphaeridium guchchaensis*** (holotype), displaying long and flexuous processes emerging from the vesicle in bunches and dark basal plugs (arrow indicating a cluster of processes and a basal dark plug); well CH-A, depth-int. 1790-95m/2, EF. F69/1; 3. ***Chambalasphaeridium guchchaensis***, showing long, homomorphic, flexuous processes emerging from the vesicle in bunches and the basal plug (arrow showing a cluster of processes and a basal plug); well CH-A, depth-int. 1790-95m/1; EF. W27/2; 4. ***Chambalasphaeridium guchchaensis***, displaying flexuous cylindrical processes emerging from the vesicle in bunches and dark basal plugs; well CH-A, depth-int. 1710-15m/1, EF. M41; 5. ***Densisphaera arista,*** showing opaque central body, with unevenly distributed, heteromorphic processes, formed by translucent external membrane, and processes showing the multifurcate terminal ends (arrow showing a process with multifurcate terminal ends); well CH-A, depth-int. 1790-95m/1, EF. M55/4; 6. ***Densisphaera arista,*** showing dense central body and irregularly distributed heteromorphic processes formed by translucent external membrane, and processes with multifurcate terminal ends (arrows showing processes with multifurcate distal ends); well CH-A, depth-int. CHA-A; 1770-75m/1; 96x50.5; EF. M55/4.

Plate V



Chambalasphaeridium guchchaensis n. sp.
(Pl. V, figs. 1- 4)

Holotype: Pl. V, fig. 2, well CH-A, depth-int. 1790-95m, slide no. 2; microscope coordinate 111x68 (EF. F69/1); Khardeola Formation (Lower Vindhyan Group) Chambal Valley, Vindhyan Basin, India.

Paratype: Pl. V, fig. 1, well CH-A, depth-int.1790-95m, slide no. 1; microscope coordinate 100x57 (EF. R58/1).

Derivation of name: The species *C. guchchensis* is named after the Sanskrit word "*guchcha",* meaning cluster or bunch that reflects the nature of the processes that emerge from the vesicle in bunches.

Locus typicus: Well CH-A, depth-int. 1790-95m, Khardeola Formation, Lower Vindhyan Group, Chambal Valley, Vindhyan Basin, India.

Stratum typicus: Shale and siltstone sedimentary rocks in well CH-A, depth-int. 1790-95m, Khardeola Formation, Lower Vindhyan Group, Chambal Valley, Vindhyan Basin, India.

Material: Sixteen specimens from Khardeola Formation and Sawa Sandstone (Lower Vindhyan Group) in bore hole CH-A between the depth-interval 1690-1795m and eleven specimens from lower part of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3085-3180m.

Species diagnosis and description: Vesicle medium to large size, subcircular to oval, originally sphaerical, with thin and hyaline vesicle-wall surface. Processes are simple, long, homomorphic, processes emerge from the vesicle in bunches of 3, 4 or even more. Base of the each bunch is dark and thickened, forming a distinct basal plug. Processes thin, cylindrical, distally become slender and often flexuous that taper into sharp-pointed tips. Individual process in each bunch/cluster is attached with the vesicle through a dark and thickened basal plug. Each cluster is clearly separated from the adjacent clusters.

Dimensions: Vesicle diameter 48-69µm, processes length 9-11µm (N = 8).

Genus ***Densisphaera*** Nagovitsin and Moczydlowska, in Moczydlowska and Nagovitsin, 2012

(*Type species*: *Densisphaera arista* Nagovitsin and Moczydlowska n. sp., in Moczydlowska and Nagovitsin, 2012. Ura formation (Ura River section), Patom Uplift, East Siberia)

Densisphaera arista Nagovitsin and Moczydlowska, 2012
(Pl. V, figs. 5-6)

Densisphaera arista Nagovitsin and Moczydlowska n. sp., in Moczydlowska and Nagovitsin, 2012, p. 15, figs. 6A–F.

Material: Eight specimens from Khardeola Formation and Sawa Sandstone (Lower Vindhyan Group) in well CH-A between the depth-interval 1690-1915m and ten specimens from lower part of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3085-3305m.

Description: Vesicle medium to small size, with dark and opaque internal (central) body and broad external translucent membranous layer, formed by unevenly distributed heteromorphic processes. Processes are predominantly cylindrical with variable wide bases, differentiated in their terminal portions into irregular short branches or with multfurcate distal ends. Simple, thin and slender cylindrical processes with sharp-pointed tips are also present in between the broad cylindrical processes.

Dimensions: Vesicle diameter 65-80µm, process length 8-10µm (N = 4).

Remarks: Specimens of *Densisphaera arista* recorded from the Lower Vindhyan Group are relatively smaller in size than those recorded from the Ura Formation (early Ediacaran) of Patom Uplift, East Siberia by Moczydlowska and Nagovitsin (2012).

Densisphaera fistulosa Nagovitsin and Moczydlowska, 2012
(Pl. VI, figs. 1-2)

Densisphaera fistulosa Nagovitsin and Moczydlowska, 2012 n. sp., in Moczydlowska and Nagovitsin – 2012, p. 15, figs. 6G–M.

Material: Twenty specimens from sedimentary rocks of the Lower Vindhyan Group in well CH-A between the depth-interval from 665-1795m and sixteen specimens from middle parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 2750-3090m.

Description: Vesicle medium to small size, circular to subcircular. Vesicle double-walled, consisting of internal dark body, and external translucent membranous layer that forms the heteromorphic irregular processes or protrusions of irregular shapes and sizes. The internal body thickened, with clearly defined outline, and surface having small irregular microfolds. External membranous layer bears widely spaced, irregularly distributed, robust, short, heteromorphic protrusions or processes. Processes mainly tubular with broad conical bases and blunt tips, others are cylindrical with truncated to sharp-pointed tips.

Dimensions: Vesicle diameter 52-67µm, process length 7-8µm (N = 6).

Distribution: Rare in Satola and Sand subgroups and common in Lasrawan and lower parts of Khorip subgroups in wells CH-A and SK-A. Rare in the middle parts of the undifferentiated Lower Vindhyan succession in well PL-A.

Genus ***Gyalosphaeridium*** Zang in Zang and Walter, 1992, emend. Grey, 2005

(*Type species*: *Gyalosphaeridium pulchrum* Zang in Zang and Walter, 1992 emend. Grey, 2005. Pertatataka Formation, Ediacaran, Amadeus Basin, Australia)

Remarks: The generic definition of *Gyalosphaeridium* as originally outlined by Zang in Zang and Walter (1992) and

EXPLANATION OF PLATE VI

1. ***Densisphaera fistulosa*** showing thick-walled, dark central body and unevenly distributed heteromorphic processes formed by external thin translucent layer; well CH-A, depth-int. 1710-15m/1, EF. V33/1; 2. ***Densisphaera fistulosa*** displaying thick-walled, dense inner body and external membranous layer forming heteromorphic, irregular processes or protrusions; well CH-A, depth-int. 1710-15m/1, EF. N23/3; 3. ***Gyalosphaeridium multispinulosum*** showing biform, heteromorphic, cylindrical processes having dark bulbous bases with distally slender and sharp-pointed tips; well CH-A, depth-int. 1770-75m/1, EF. Q45; 4. ***Gyalosphaeridium multispinulosum*** showing long, biform, heteromorphic processes with dark bulbous bases, distally slender with sharp-pointed tips; well PL-A, depth-int. 3085-90m/1, EF.M50; 5. ***Gyalosphaeridium pulchrum*** showing long, densely arranged, heteromorphic cylindrical processes with widened bases and sharp-pointed and blunt tips; well CH-A, depth-int.1790-95m/2, EF. L48/2; 6. ***Gyalosphaeridium pulchrum*** displaying heteromorphic cylindrical processes, with sharp-pointed and blunt tips; well PL-A, 3125-30m/1, EF. K68/1.

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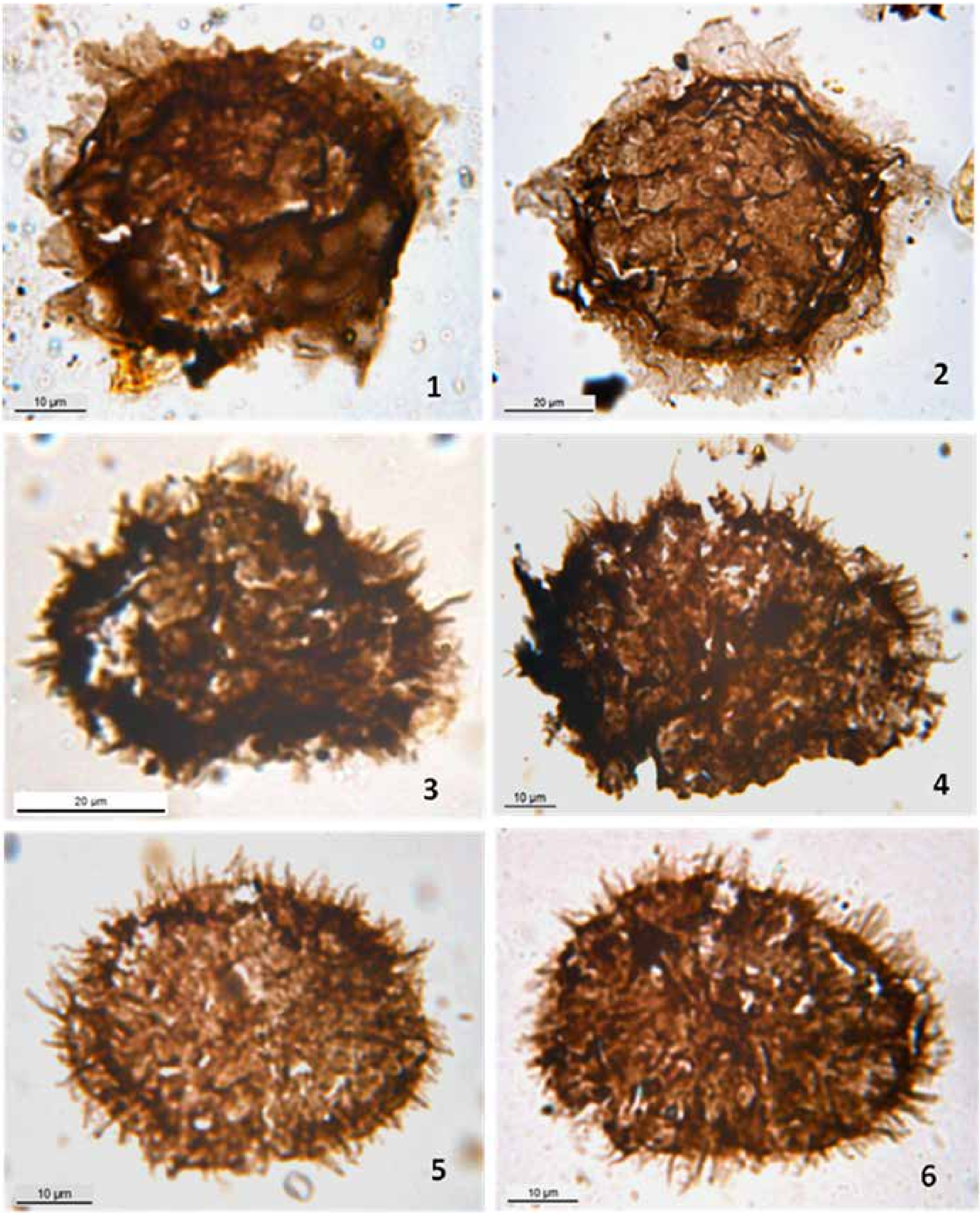
Plate VI



later emendation by Grey (2005) are followed here for the identification of various species of the genus. In the Chambal Valley assemblages, large numbers of specimens attributable to *Gyalosphaeridium* are recorded. The recorded specimens are differentiable in two species of the genus based on morphological features of the processes on the vesicle. Specimens having heteromorphic to homomorphic, predominantly cylindrical processes with truncated to rounded distal ends are grouped into *G. pulchrum*. Specimens with long, elongated and flexuous biform processes with broad bulbus bases, and slender distal portion with sharp-pointed tips are identified as *G. multispinulosum* Grey (2005).

Gyalosphaeridium multispinulosum Grey, 2005
(Pl. VI, figs. 3-4)

Gyalosphaeridium multispinulosum Grey, 2005, pp. 273-277, fig. 11I, 44I, 179A-D, 180A-E, 181-184. – Willman *et al.* , 2006, pl. I, fig. 5.

Material: Twenty four specimens from Khardeola Formation, Sawa Sandstone and Palri Shale (Lower Vindhyan Group) in well CH-A between the depth-interval 1510-187m, and twenty specimens from lower part of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3085-3305m.

Description: Vesicle subcircular to oval, originally sphaerical, vesicle-wall thick and dark. Vesicle bears numerous, densely arranged, evenly distributed, long and heteromorphic processes. Processes predominantly cylindrical, biform, with dark swollen broad bases that sharply taper distally into thin, slender and flexuous processes. Distal ends of the processes sharp-pointed.

Dimensions: Vesicle diameter 45-80µm, process length 8-11µm (N = 5).

Distribution: Common in the Khardeola Formation, rare in the Sawa Sandstone and Palri Shale in well CH-A and SK-A. Common to rare in the lower part of the undifferentiated Lower Vindhyan succession in well PL-A.

Gyalosphaeridium pulchrum Zang in Zang and Walter, 1992
emend. Grey, 2005
(Pl. VI, figs. 5- 6)

Gyalosphaeridium pulchrum Zang in Zang and Walter, 1992.
Gyalosphaeridium pulchrum Zang in Zang and Walter.1992 – Grey. 2005, pp. 354-355
– Willman *et al*., 2006, p. 29, pl. I, fig. 5, pl. III, figs. 1-6.
Gyalosphaeridium pulchrum Zang in Zang and Walter, 1992 – Liu *et al*., 2013, p. 41, figs. 13G.

Material: More than forty specimens from the Lower Vindhyan Group in well CH-A between the depth-interval 462-1871m, and thirty specimens from lower and middle parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 2850-3305m.

Description: Vesicle small to medium size, subcircular to oval, with thickend vesicle-wall. Vesicle bears numerous, densely arranged but clearly separated, long and heteromorphic processes. Processes are predominantly cylindrical, with slightly widened and thickened bases. Processes distally become slender that tapers into narrow sharp-pointed tips, some processes are also with blunt tips.

Dimensions: Vesicle diameter 49-72µm, process length 6-9µm (N = 8).

Genus ***Knollisphaeridium*** Willman and Moczydlowska, 2008

(*Type species*: *Knollisphaeridium maximum* (Yin, L., 1987) Knoll, 1992, Doushantuo Formation, Xiaofenghe section, Hubei Province, China)

Knollisphaeridium triangulum (Willman and Moczydlowska, 2008) emend. Xiao, Zhou, Liu, Wang and Yuan, 2014
(Pl. VII, figs. 1 - 2)

Echinosphaeridium maximum (Yin, L., 1987) Knoll, 1992, pp. 765-766. - Yuan and Hofmann, 1998, p. 202, fig. 8A–8D.
Partim Echinosphaeridium maximum (Yin, L., 1987) Knoll, 1992- Zhang, Yin, L., Xiao and Knoll, 1998, figs. 6.7, 6.8
Echinosphaeridium maximum (Yin, L., 1987) Knoll, 1992- Xiao And Knoll, 1999, p. 239, fig. 11A–11C;
Partim Echinosphaeridium maximum (Yin, L., 1987) Knoll, 1992, Yin C., Liu, G., Wang, Tang and Liu, 2007, pl. 11, Fig. 4
Echinosphaeridium triangulum (Zang in Zang and Walter, 1992) *Knollisphaeridium. triangulum* (Yin, L., 1987) Knoll, 1992 - Grey, 2005, p. 255, fig. 156.
Echinosphaeridium triangulum ? Zang in Zang and Walter (1992) -Willman, Moczydłowska and Grey, 2006, p. 29, pl. 6, figs. 5, 6;
Knollisphaeridium. triangulum Willman and Moczydlowska – Liu *et al.,* 2013, fig. 13H. – Xiao *et al.,* 2014, pp, 30-31, fig. 20.1-20.5.

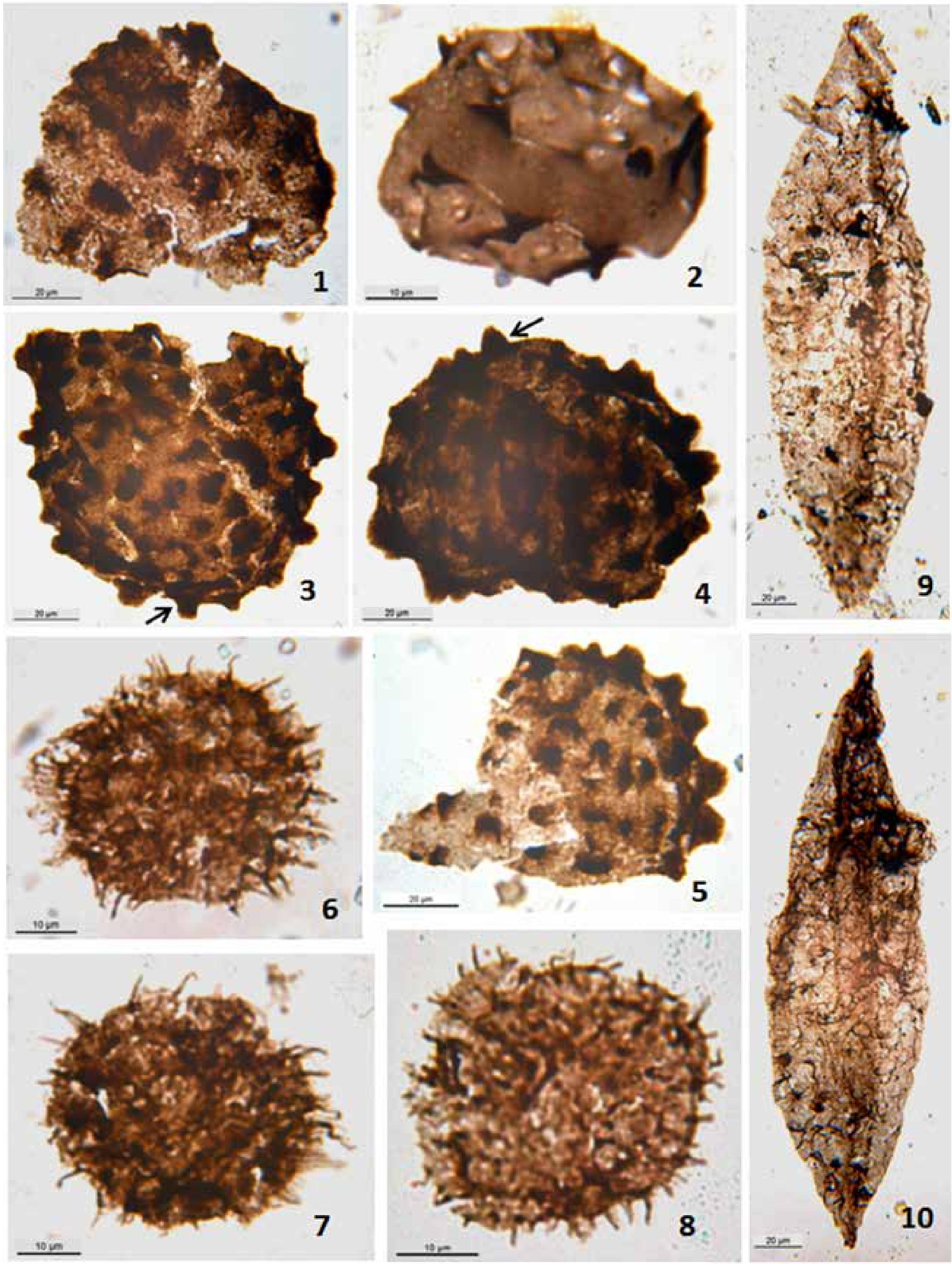
Material: Sixteen specimens from the sedimentary rocks of lower and middle parts of the Lower Vindhyan Group in well CH-A between the depth-interval 665-1515m, and five specimens from middle part of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 2850-3035m.

Description: Vesicle small to medium size, subcircular to subtriangular, with hyaline vesicle-wall surface. Vesicle bears few, well-developed, widely separated, heteromorphic, biform, conical processes. Processes breadth is more than the height. Conical processes domical shape, with exceptionally broad bases that sharply taper into cylindrical to spinose processes at distal portion. Distal end of the processes are sharp-pointed to blunt.

EXPLANATION OF PLATE VII

1. ***Knollisphaeridum triangulum*** showing sparsely distributed, short, conical to echinate, biform processes with wide, expanded conical base and small, thin apical spine; well CH-A, depth-int. 1040-45m/1, EF. L38/4; 2. ***Knollisphaeridum triangulum*** showing widely spaced, conical, biform processes with expanded conical bases and small apical spines; well CH-A, depth-int. 1140-45m/1, EF. Q28; 3. ***Sinosphaera rupina*** showing short, cylindrical and conical processes, with blunt and pointed tips (arrow indicating a cylindrical process with blunt tips); well CH-A, depth-int. 1040-45m/1, EF. D45/1; 4. ***Sinosphaera rupina*** showing bimorphic, conical and cylindrical processes, with broad bases and blunt tips (arrow indicating a conical process with broad base and sharp-pointed tips); well CH-A,depth-int. 1040-45m/2, EF. P61; 5. A broken specimen of ***Sinosphaera rupina*** showing short , stout, cylindrical processes, with wide bases and blunt tips; well CH-A, depth-int. 1040-45m/1; 98x45, EF. D45/1; 6. ***Tanarium anozos*** displaying long, flexuous processes with sharp-pointed tips; well CH-A, depth-int. 1790-95m/2, EF. U50/1; 7. ***Tanarium anozos*** showing long, widely spaced, distally flexuous cylindrical processes, with sharp-pointed tips; well CH-A, depth-int. 1810-15m/1, EF. O60/1; *8.* ***Tanarium conoideum*** showing evenly distributed, short, conical processes with sharp-pointed tips; well CH-A, depth-int. 1790-95m/1, EF. J56/3; 9. ***Schizofusa risoria*** showing fusiform vesicle and a prominant median slit bordered by thickened lips; well PL-A, 3175-80m/1, EF. M43/1; 10. ***Schizofusa risoria*** showing a prominent longitudinal fold on median slit; well PL–A, 3150-55m/1, EF. W41/1.

Plate VII



Dimensions: Vesicle diameter 55-70µm, process length 5-7µm, process breadth 7-8µm (N = 5).

Genus **Schizofusa** Yan, 1982

(*Type species*: *Schizofusa sinica* Yan, 1982, Chuanlinggou Formation, northern China)

Schizofusa risoria Grey, 2005
(Pl. VII, figs. 9 - 10)

Schizofusa risoria n. sp. Grey, 2005, pp. 189– 191, fig. 69A-C.

Schizofusa risoria Grey – Willman *et al*., 2006, pp. 31-32, Pl.IV, fig.4. Willman and Moczydlowska, 2008, p. 525, fig. 11A-B.

Material: More than twenty specimens from sedimentary rocks of the Lower Vindhyan Group in well CH-A between the depth-interval 665-1871m and more than twenty five specimens from lower and middle parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 2750-3305m.

Description: Vesicle medium to large size, fusiform in shape, with sharp-pointed longitudinal ends. Vesicle surface is thin, hyaline and with irregular microfolds. A prominnant, longitudinal, slit-like aperture divides the vesicle into two portions. Longitudinal slit is bordered by thickened lips.

Dimensions: Vesicle length 100--310µm, vesicle width 40-70µm (N = 8).

Distribution: Subdominant to common in Khardeola Formation, Sawa Sandstone and Palri Shale, rare in Lasrawan and lower parts of Khorip subgroups in wells CH-A and SK-A. Subdominant to common in lower part and rare in middle parts of the undifferentiated Lower Vindhyan Group in well PL-A.

Genus **Sinosphaera** Zhang, Yin, Xiao, Knoll, 1998 emend. Xiao, Zhou, Liu, Wang and Yuan, 2014

(*Type species*: *Sinosphaera rupina* Zhang, Yin, Xiao, Knoll, 1998. Upper Doushantuo Formation, Shipai Section Terminal Proterozoic, Hubei Province, China)

Sinosphaera rupina Zhang, Yin, Xiao, Knoll, 1998 emend. Liu, Xiao, Yin, Chen, Zhou and Li, 2014
(Pl. VII, figs. 3 - 5)

Sinosphaera rupina n. Sp. – Zhang *et al.,* 1998, pp. 38–40, figs. 11. 4-11.10.

?*Sinosphaera rupina* Zhang *et al.*, 1998 – Grey, 2005, pp. 291–292, figs. 201A–D.

?*Sinosphaera rupina* Zhang *et al.*, 1998 – Willman *et al*., 2006, p. 32, pl. II, 4.

?*Sinosphaera rupina* Zhang *et al.*, 1998 – Willman and Moczydlowska, 2008, p. 526, fig. 11D-F.

?*Sinosphaera rupina* Zhang *et al.*, 1998 – Vorob'eva *et al*., 2008, fig. 2i.

?*Sinosphaera rupina* Zhang *et al.*, 1998 – Golubkova *et al.,* 2010, pl. 4, fig. 5.

?*Sinosphaera rupina* Zhang *et al.*, 1998 – Sergeev *et al.,* 2011, p. 1005, fig. 7.2 -7.4.

Sinosphaera rupina Zhang *et al.*, 1998 – Liu *et al.,* 2014, p. 106-109, fig. 72.2, 73.7-73.9, 74.1-74.7.

Material: Twenty specimens from sedimentary rocks of the Lower Vindhyan Group in well CH-A between the depth-interval 665-1515m, and sixteen specimens from lower and middle parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 2750-3035m.

Descriptions: Vesicle small to medium size, subcircular to oval, originally spheroidal, vesicle-wall thick. Vesicle bears short, widely distributed, evenly arranged, heteromorphic (bimorph) processes of conical and cylindrical shapes of variable sizes. Small processes uniformly conical with broad bases and sharp-pointed tips scattered in between the relatively large cylindrical processes. Bases of cylindrical processes are with broad that distally tapers into blunt tips. Processes hollow inside and freely communicate with the vesicle cavity

Remarks: Specimens of *S. rupina* recorded from sedimentary rocks of the Lower Vindhyan Group are relatively smaller in size-range than those recorded from the Doushantuo Formation, China.

Dimensions: Vesicle diameter 93- 102µm, process length 8-12µm, base width 6-8µm (N = 4).

Genus **Tanarium** Kolosova, 1991, emend. Moczydlowska, Vidal and Rudavskaya, 1993

(*Type species*: *Tanarium conoideum* Kolosova, 1991, emend. Moczydlowska, Vidal and Rudavskaya, 1993. Kursov Formation, Ediacaran, Yakutia, Siberian Platform)

Tanarium anozos Willman, in Willman and Moczydłowska, 2008
(Pl. VII, figs. 6 -7)

Tanarium anozos Willman, n. sp. – Willman and Moczydłowska, 2008, p. 526, fig. 13A–F (holotype fig. 13A).

Tanarium conoideum Kolosova–Vorobeva *et al.,* 2008, fig. 2a.

Tanarium conoideum (Kolosova) emend. Moczydłowska, Vidal and Rudavskaya–Golubkova *et al.,* 2010, pl. IV, fig. 2.

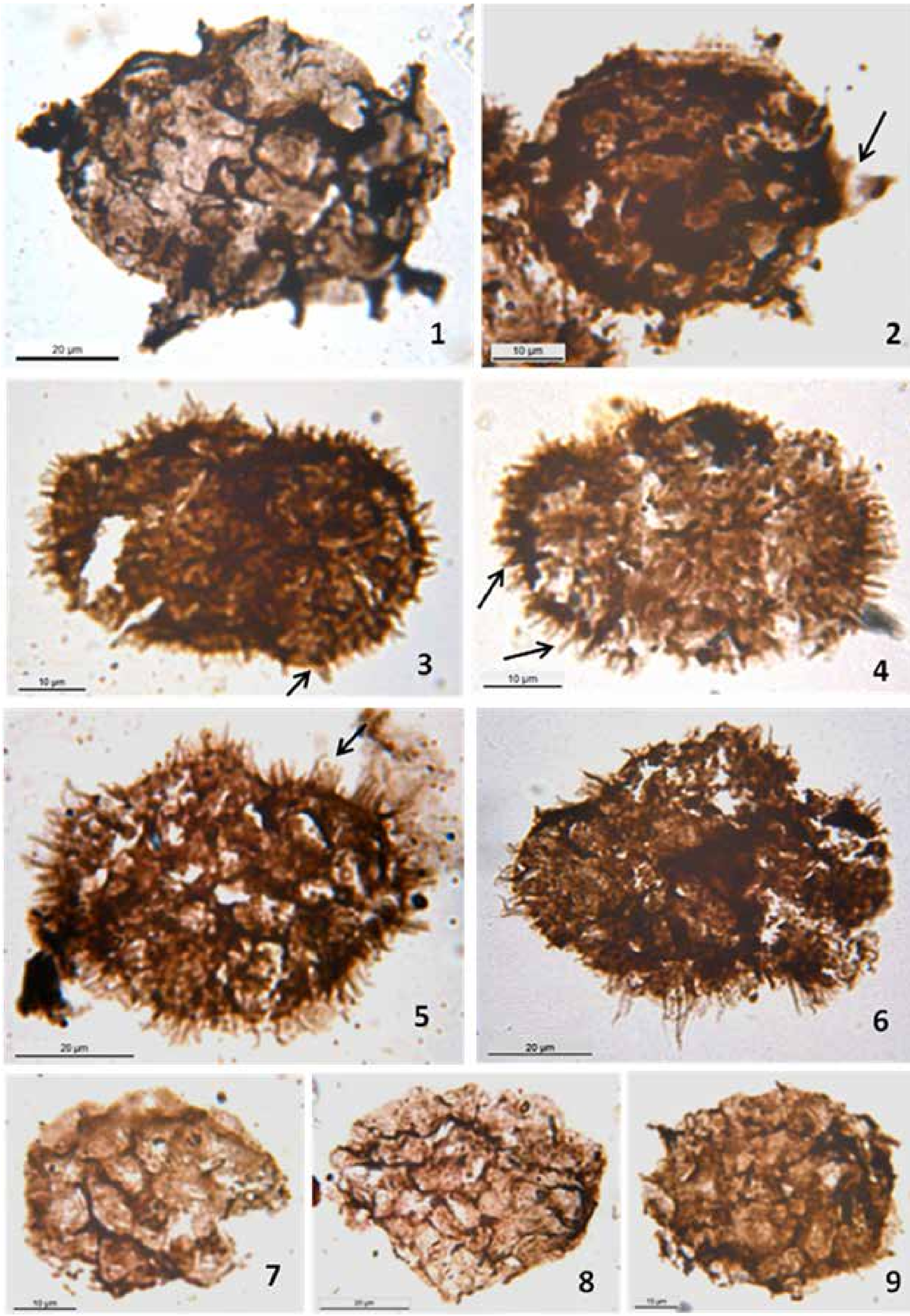
Tanarium anozos Willman, 2008 – Liu *et al.* 2011, fig. 11B.

Tanarium anozos Willman, 2008 – Moczydlowska and Nagovitsin., 2012, p.18, fig. 8A-C. – Liu *et al*., 2013, fig. 11B.

EXPLANATION OF PLATE VIII

1. ***Tanarium tuberosum*** displaying few, unevenly distributed, heteromorphic, conical to tubular processes; well PL-A, depth-int. 2900-05m/1, EF. O42/1; 2. ***Tanarium tuberosum*** showing widely spaced, heteromorphic, conical and cylindrical processes, with sharp-pointed and blunt tips (arrow showing a process having wide base and sharp pointed tip); well PL-A, depth-int. 3085-90m/1, EF. E34/1; 3. ***Triloboacanthosphaeridium tripartita*** showing trilobate elliptical vesicle and heteromorphic cylindrical processes (arrow indicating a cylindrical process with bulbous base and sharp-pointed tip); well CH-A, depth-int. 1710-15m/1, EF. U42/4; 4. ***Triloboacanthosphaeridium tripartita*** (holotype), displaying three lobes of the vesicle formed by two prominant longitudinal ruptures and heteromorphic processes with dark swollen bulbous bases and sharp-pointed tips (arrows indicating processes with dark swollen bases and sharp-pointed tip); well PL-A, depth-int. 3085-90m/2, EF. O29/3; 5. ***Triloboacanthosphaeridium tripartita*** showing trilobate vesicle with a prominent outward median buldge, and long heteromorphic cylindrical and tubular processes (arrow indicating a tubular process with multifurcate terminal end); well PL-A, depth-int. 3085-90m/1, EF. N39; 6. ***Triloboacanthosphaeridium tripartita*** (paratype) showing a prominent outward bulge of the vesicle and heteromorphic cylindrical processes with sharp-pointed tips; well CH-A, 1750-55m/2, EF. W30/1; 7. ***Cristallinium cambriense*** showing polygonal fields on the vesicle, with cristate ornamentation on the raised field- margins; well PL-A, depth-int. 3150-55m/1, EF. N71; 8. ***Cristallinium cambriense*** showing polygonal fields on the vesicle, with cristate ornamentation over the raised field- margins; well PL-A, depth-int. 3150-55m/1, EF. W56/1; 9. ***Cristallinium*** cf. ***C. cambriense*** showing polygonal fields on the vesicle, with dentate ornamentation over the raised field- margins; well CH-A, depth-int. 1790-95m/1, EF. W36/3.

Plate VIII



Material: Four specimens from Khardeola Formation and Sawa Sandstone (Lower Vindhyan Group) in well CH-A between the depth-interval from 1690-1815m and twelve specimens from lower and middle parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 2850-3150m.

Description: Vesicle circular to subcircular, originally sphaerical, vesicle-wall thin and hyaline. Vesicle bears evenly arranged, clearly separated, long, homomorphic processes. Processes are simple, cylindrical, almost uniform in length, slightly swollen at bases; distal part of processes slender and flexuous, tapper into needdle-like shape with sharp-pointed tips, terminal ends of some proceesses slightly bent. Processes hollow and freely communicate with the vesicle cavity.

Dimensions: Vesicle diameter 45-70 µm, process length 8-14µm long (N = 5).

Tanarium conoideum Moczydlowska,
Vidal and Rudavskaya, 1993
(Pl. VII, fig. 8)

Baltisphaeridium primarium Jankauskas – Pyatiletov, 1980, p.11, pl. 1, figs. 1- 4. – Pyatiletov and Rudavskaya, 1985, p. 152, pl. 63, Figs. 1- 4. –Rudavskaya and Vasileva, 1989, pl. 1, fig. 7.

Tanarium conoideum Kolosova, n. gen. & n. sp. – Kolosova, pp. 25-26, 1990, pl. 1, figs.1-2 (unpublished manuscript) (*Nomen nudem*)

Tanarium conoideum Kolosova, sp. nov. – Kolosova, 1991, p. 56, fig. 5: 1 – 3.

Pro parte Hocosphaeridium scaberfacium n. gen.& n. sp. – Zang in Zang and Walter, 1992a, p. 61, fig. 45A-F (non-G).

Goniosphaeridium sp. A – Zang in Zang and Walter, 1992a, 1992, p. 54, fig. 45H.

Tanarium conoideum Kolosova, 1991 emend. Moczydłowska, Vidal and Rudavskaya, 1993, pp. 514–516, text-fig. 10C, D. – Knoll, 1994, fig. 4G.

Hocosphaeridium scaberfacium Zang in Gravestock *et al.,* 1997, p. 91, fig. E.

Goniosphaeridium conoideum (Kolosova) new combination – Zhang, Yin, Xiao and Knoll, 1998, p. 32, fig. 9.1-9.4.

Tanarium conoideum (Kolosova, 1991, emend. Moczydłowska, Vidal and Rudavskaya, 1993)– Moczydlowska, 2005, pp. 302-303, figs. 7A, C, E. - Grey, 2005, pp. 299- 303, figs.212A-D, 213A-D. – Willman *et al.*, 2006 p. 32, pl. VI, 1-2. – Golubkova and Raevskaya, 2007, pl. I:7.

2007 *Tanarium conoideum* Kolosova–Vorobeva *et al.,* pl. ID. – Willman and Moczydłowska, 2008, p. 526–527, Fig. 12C.

Tanarium conoideum Kolosova–Vorobeva *et al*., 2008, fig. 2a (=T. anozos) (Non).

Tanarium conoideum Kolosova, 1991, emend. Moczydłowska, Vidal and Rudavskaya, 1993–Vorobeva *et al.,* 2009, p. 180–182, fig. 7:4, 7.

Tanarium conoideum (Kolosova) emend. Moczydłowska, Vidal et Rudavskaya–Golubkova *et al.,* 2010, pl. IV:2 (=T. anozos).

Tanarium conoideum Kolosova, 1991, emend. Moczydłowska *et al.,* 1993 – Liu *et al.,* 2011, fig. 11A. – Sergeev *et al.,* 2011, p.1005, fig. 6.1, 2. – Vorobeva *et al.,* 2011, p.166, fig. 4.e. – Moczydlowska and Nagovitsin., 2012, p.18, Fig. 8K. – Liu *et al*., 2013, fig. 11A. – Liu *et al.,* 2014, p.109, figs. 76.2, 77.1-6. – Xiao *et al.,* 2014, p.51, fig. 33.1-6.

Material: Five specimens from Khardeola Formation and Sawa Sandstone (Lower Vindhyan Group) in well CH-A between the depth-interval 1600-1815m, and four specimens from lower parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3085-3180m.

Description: Vesicle small to medium size, circular to subcircular, with hyaline vesicle-wall. Vesicle bears widely placed, evenly distributed, heteromorphic processes. Processes mainly short, narrow with conical bases and sharp-pointed tips, rarely curved at distal end, others are cylindrical with truncated tips. Processes hollow and freely communicating with the vesicle cavity.

Dimensions: Vesicle diameter 47-76µm, process length 12-14µm (N = 5).

Tanarium tuberosum Moczydlowska,
Vidal and Rudavskaya, 1993
(Pl. VIII, figs. 1 - 2)

Asterocapsoides sinensis (Yin and Li,) - Knoll (1992), pp. 762–764, pl. 6, figs. 5–6 (*Non* 1978).

Baltisphaeridium primarium Jankauskas- Rudavskaya and Vasileva, 1989, pl. 2, fig. 3.

Tanarium tuberosum n. sp. - Moczydłowska *et al*., 1993, pp. 516–518, text-fig 15A–D.

Non 1998 *Asterocapsoides sinensis* (Yin and Li, 1978,emend.) - Zhang *et al*., 1998, pp. 24, fig. 5.10.

Tanarium tuberosum Moczydlowska *et al*. – Faizullin, 1998, pl. II, fig. 1.

Tanarium conoideum Kolosova–Faizullin, 1998, pl. II, fig. 2–4, 8.

Tanarium stellatum Nagovitsin et M. Faizullin sp. n. –Nagovitsin *et al*., 2004, p. 14, pl. II, figs 16–18.

Tanarium tuberosum Moczydlowska *et al*. – Golubkova and Raevskaya, 2007, pl. I, fig. – Willman and Moczydłowska, 2008, pp. 527–528, fig. 12F. –Vorobeva *et al*., 2009, p. 182, fig. 7:6, 8.

Golubkova *et al.,* 2010, pl. II:2, pl. III:11.

Lophosphaeridium sp. – Golubkova *et al.,* 2010, pl. II:4.

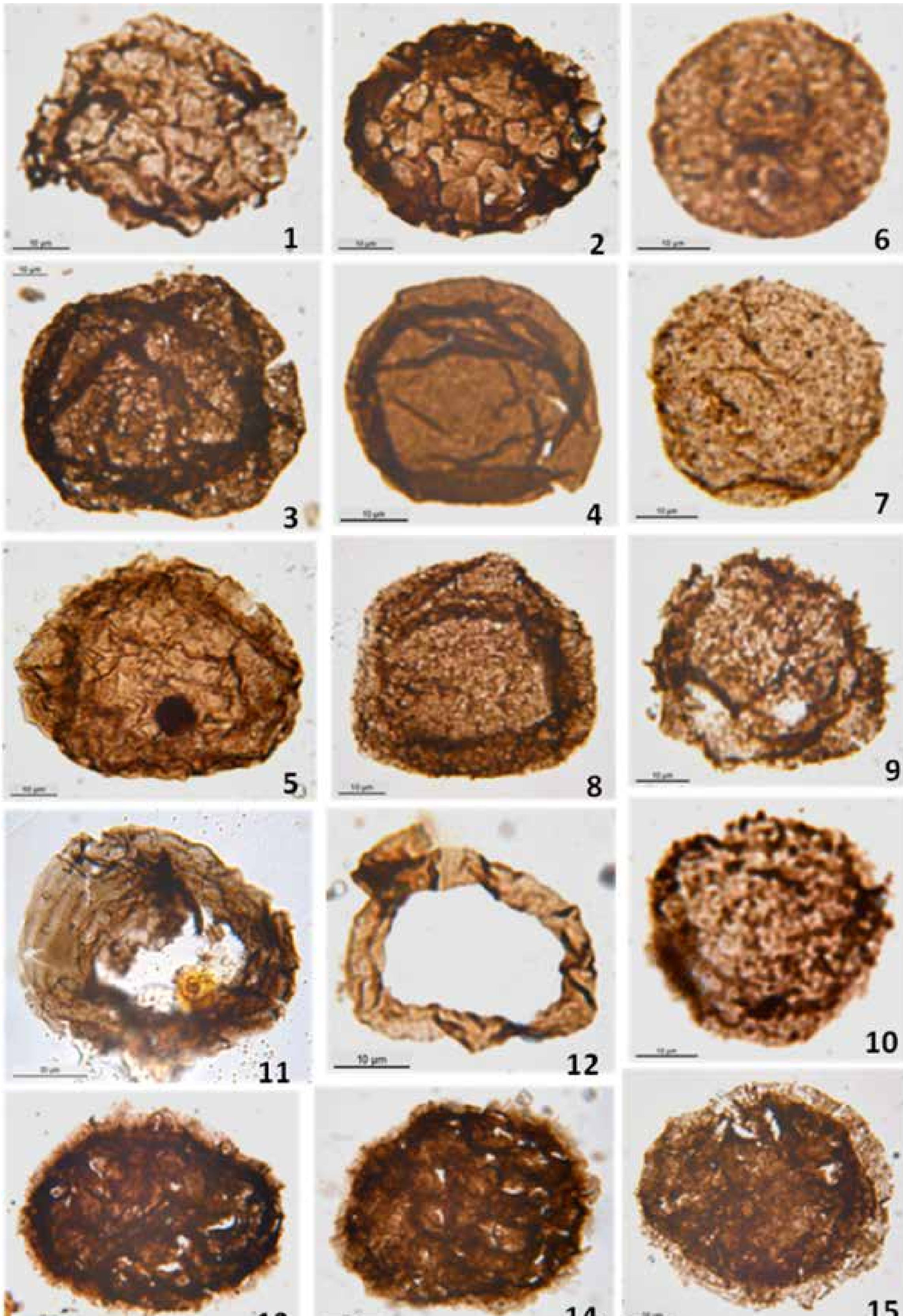
Tanarium tuberosum Moczydlowska, Vidal and Rudavskaya, 1993 – Sergeev *et al.,* 2011, p. 1006, fig. 6.3. – Moczydlowska and Nagovitsin*.,* p. 20, fig. 8G-J. – Liu *et al*., 2013, fig. 13C.

Material: Sixteen specimens from the lower parts of the Lower Vindhyan Group in well CH-A between the depth-interval 1140-1795m and twenty specimens from lower parts of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 2850-3155m.

EXPLANATION OF PLATE IX

1. ***Dictyotidium birvetense*** showing small polygonal fields on the vesicle, with low relief raised field-margins; well CH-A; 1710-15m/2, EF. G22/2; 2. ***Dictyotidium birvetense*** showing small polygonal fields on the vesicle, with low relief raised field-margins; well CH-A; 1040-45m//2, EF. L72/3; 3. ***Leiosphaeridia jacutica*** showing large and thick-walled vesicle with irregular curvilinear folds; well CH-A; 1810-15m/1, EF. N24; 4. ***Leiosphaeridia asperata*** showing medium-sized, smooth vesicle, with irregular folds; well CH-A; 1750-55m/1, EF. X62/1; 5. ***Leiosphaeridia tenuissima*** showing large, thin-walled, transparent vesicle, with irregular folds; well PL-A; 325-30m/1, EF. T49/4; 6. ***Lophosphaeridium jansoniusii*** showing small,densely arranged, conical processes; well CH-A, depth-int. 462-68m/1, EF. U67/2; 7. ***Lophosphaeridium rarum*** showing densely arranged, small, solid tubercles; well PL-A, depth-int. 505-10m/1, EF. U56/2/1; 8. ***Lophosphaeridium rarum*** showing densely arranged, small, solid, conical processess; well CH-A, depth-int. 1830-35/1, EF. Y47/1; 9. ***Asteridium lanatum*** showing closely placed, small, tuburculate processes, with pointed to acuminating tips; well CH-A, depth-int. 1710-15m/2, EF. D46/4; 10. ***Lophosphaeridium tentativum*** showing small, densely arranged, solid, tubercles; well PL-A, depth-int. 2875-80/1, EF. M44/1; 11. ***Obruchevella valdaica*** showing tightly placed and helically-coilled filament; well PL-A, depth-int. 3090-95/1, EF. R31; 12. ***Obruchevella parva*** showing a helix of coiled filament with cross-partitions of trichome; well PL-A, depth-int. 3090-95/1, EF. R31; 13. ***Vandalosphaeridium reticulatum*** displaying sparsely distributed, short, cylindrical processes, supporting outer rmembranous layer; well PL-A, depth-int. 3150-55m/1, EF.U45; 14. ***Vandalosphaeridium reticulatum*** displaying sparsely distributed, small cylindrical, supporting the outer membranous layer; well SK-A, depth-int. 1550-55m/1, EF.Q48/2; 15. ***Pterospermopsimorpha insolita*** showing dense body and outer transluscent peripheral rim; well CH-A, depth-int. 1790-95/2, EF. J29/1.

Plate IX



PRASAD AND ASHER

Description: Vesicle subcircular to oval, with irregular outline, vesicle-wall hyaline. Vesicle bears few, widely placed, and unevenly distributed, short, stout, heteromorphic processes. Processes are predominantly conical, with broad bases and sharp-pointed tips, rarely cylindrical, with blunt tips. Processes bases are wide, dark and swollen, distal ends of some processes thickened and dark. Processes hollow and freely communicate with the vescle cavity.

Dimensions: Vesicle diameter 47-80μm, process length 12-16μm (N = 3).

Genus ***Triloboacanthosphaeridium*** n. gen.

(*Type species*: *Triloboacanthosphaeridium tripartita* n. gen. et sp., well PL-A, undifferentiated Lower Vindhyan Group, Chambal Valley, Vindhyan Basin, east Rajasthan, India)

Derivation of name: The new genus is named after the trilobate shape of vesicle (Trilobo) and having numerous acanthomorphic processes over the vesicle.

Generic diagnosis: Vesicle small to medium size, transversely oval to elliptic, with undulating peripheral margins. Vesicle subdivided into three distinct parts by two prominant longitudinal vesicle-incisions (ruptures) or by the outward bulge of the median part of the vesicle. Vesicle bears closely arranged, long, heteromorphic, cylindrical processes, having dark swollen bases and sharp-pointed to blunt tips, vesicle rarely bears conical processes of broader diameter also, with multifurcate terminal ends. Processes uniformally distributed over the vesicle.

Comparison: The new genus *Triloboacanthosphaeridium* is distinguishable from the other known complex acanthomorphs in having the trilobate vesicle formed by the two distinct vesicle-incisions or by a prominent outward medial bulge of the vesicle, and bearing the heteromorphic processes uniformally distributed over the vesicle.

Triloboacanthosphaeridium tripartita n. sp.
(Pl. VIII, figs. 3- 6)

Holotype: Pl. VIII, fig. 4; well PL-A, depth-int. 3085-90m, slide no. 2; microscope coord. 102x29 (EF. O29/3); lower parts of Lower Vindhyan Group, Chambal Valley, Vindhyan Basin, India.

Paratype: Pl. VIII, fig. 6; well CH-A, depth-int. 1750-55m, slide no. 2; microscope coord. 95x30 (EF. W30/1); Lower parts of Lower Vindhyan Group, Chambal Valley, Vindhyan Basin, India.

Derivation of name: The species is named after sub- division of the vesicle into three distinct parts by two strong longitudinal incisions or by median outward bulge of the vesicle.

Locus typicus: well PL-A, depth-int. 3085-90m, Lower Vindhyan Group, Chambal Valley, east Rajasthan, India

Stratum typicus: Shale and siltstone of lower parts of the Lower Vindhyan Group, Chambal Valley, Vindhyan Basin, India

Material: Twelve specimens from Khardeola Formation (Lower Vindhyan Group) in well CH-A between the depth-interval 1690-1815m and twenty two specimens from lower part of the undifferentiated Lower Vindhyan succession in well PL-A between the depth-interval 3085-3305m.

Diagnosis and descriptions: Vesicle small to medium size, transversely oval to elliptic, originally sphaeroidal. Vesicle is subdivided laterally into three distinct parts by two prominent longitudinal vesicle-ruptures (vesicle-incisions) or subdivided in three lobes formed by the outward bulge of the median portion of the vesicle. Median portion of the vesicle is relatively larger than the lateral lobes. Vesicle bears densely arranged, evenly distributed, long, heteromorphic processes. Processes are predominantly cylindrical, with dark and slightly swollen bases and sharp-pointed to blunt tips. Rarely tubular processes with relatively wider diameter and multifurcate terminal ends also emerge from the vesicle. Processes hollow and freely communicate with the vesicle cavity.

Dimensions: Vesicle diameter 44-79μm, process length 5-9μm (N = 6).

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