Occurrence of helically coiled microfossil *Obruchevelia* in the Owk Shale of the Kurnool Group and its significance

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The present study reports occurrence of helically coiled microfossil *Obruchevelia* Reitlinger from the Owk Shale of the Kurnool Group from the peninsular India. The age of the Kurnool Group is poorly constrained due to the absence of direct radiometric dating and meager palaeobiological data. Occurrence of *Obruchevelia* is considered as a typical Vendian marker genus recorded mostly from close to the Precambrian–Cambrian boundary successions. Hence, the present assemblage is important to ascertain the age of the basin. In the Owk Shale, four species of *Obruchevelia*, viz., *O. delicata*, *O. parva*, *O. minor* and *O. valdaica* are recorded as organic walled microfossils. Among them *O. valdaica* is the largest in terms of size parameters. On the global scale, the recovered species occur in the Late Neoproterozoic to Early Cambrian sediments. Therefore, the occurrence of microfossil *Obruchevelia* in the Owk Shale and known burrow structures in the Narji Limestone suggest Ediacaran age close to the Cambrian for the Kurnool Basin and challenges the recently assigned Mesoproterozoic age of the basin.

1. Introduction

Carbonaceous microfossils are the important element of the Precambrian biosphere. Among them, the helically coiled microfossils though distinct, are problematic. These are broadly divided into *Obruchevelia*, *Volyniella* (subsequently merged with *Obruchevelia*), *Boruokia*, *Grypania* and *Spirillopsis*. They occur in shales, chert and carbonate rocks and are recorded from Australia, Alaska, Canada, China, Greenland, India, Mongolia, Russia and Saudi Arabia (see Peel 1988; Mankiewicz 1992; Burzin 1995). *Obruchevelia* Reitlinger is the commonly recorded helically coiled microfossil that range in age from Riphean to Devonian and most of them are reported from close to the Precambrian–Cambrian boundary successions. In Indian sedimentary successions, in extra peninsular region, these are reported from Tal Formation (Ahluwalia 2002), Infra-Krol Formation (Tiwari and Knoll

1994), Krol Formation (Kumar and Rai 1992), Buxa Formation (Shukla *et al* 2006; Tewari 2007; Tiwari and Pant 2009) and in the peninsular region in Bhander Group (Prasad *et al* 2005; Prasad 2007) and Salkhan Limestone (Rai and Singh 2004). Helically coiled microfossils of Himalaya occur in the Precambrian–Cambrian successions whereas those of the peninsular region have been suggested to be of Palaeo-Mesoproterozoic age. In the present paper, we are reporting the first occurrence of the helically coiled microfossil from the Owk Shale of the Kurnool Group in the peninsular India. All the previously reported forms were described in terms of the morphology of the helix diameter and filament diameter but data on pitch, which conveys about the tightness of the coiling, were not provided. In the present paper, the Kurnool helically coiled microfossils are taxonomically described; their preservation, affinity and age connotation have also been discussed.

Keywords. Owk Shale; Kurnool; *Obruchevelia*; helically coiled microfossils; Neoproterozoic; India.

The age of the Owk Shale as well as the entire Kurnool Group is poorly constrained due to the absence of direct radiometric dating of any of the litho-units and the palaeobiological data of the basin are also meager. Indirect evidence suggests the Mesoproterozoic age of the basin (Dongre *et al* 2008) which is contradictory to what is inferred from the available palaeobiological data. In this case, the record of genus *Obruchevella* is important to ascertain the age of the basin as it is considered as typical Vendian. It is known from cherts, shale, limestone, dolomite and phosphorite. In the Owk Shale, four species of *Obruchevella* are recorded, viz., *O. delicata*, *O. parva*, *O. minor* and *O. valdaica*. All four species have known occurrences from the Late Neoproterozoic to the Early Cambrian. Although a few (older Neoproterozoic) specimens of *Obruchevella* are known, Vendian–Lower Cambrian acme of this genus is a real phenomenon (Knoll 1996). The Owk Shale overlies the Narji Limestone from where bioturbation structures in the form of worm burrows were reported (Vijayam 1967; Arya and Rao 1979). The presence of worm burrows indicate the animal activity towards the end of uppermost Proterozoic or even the Lower Cambrian age of the strata. The occurrence of helically coiled microfossils *Obruchevella* from the Owk Shale together with the burrow structures in the Narji Limestone suggest an Ediacaran age close to the Cambrian for the Kurnool Basin. The present study, thus, challenges the recently assigned Mesoproterozoic age of the basin.

2. General geology and age

A long period of quiescence followed the Cuddapah Supergroup sedimentation in the south by the tectonic activities between 1100 and 900 Ma (Valdiya 2010). Fresh sedimentation cycle was marked with angular unconformity. This sedimentation resulted in two cycles of quartzite-limestone-shale deposition and is known as the Kurnool Group. The sediments of the Kurnool Group were invariably deposited over the different units of the Cuddapah Supergroup (figure 1a). The lithostratigraphic succession of the Kurnool Group is given in table 1. The Kurnool Group sediments are exposed in Kundair Valley in the west and the Palnad area in the northeast. In the Kundair Valley, the Kurnool Group sediments unconformably overlies the basement gneisses and different members of the underlying Papaghani and Chitravati Groups.

Impersistent horizon of 10–50 m thick conglomerate and sandstone form the base of the Banganpalle Formation. It is a source of detrital diamonds. Overlying this unit is the Narji Limestone which is extensively developed in the region. It is massive-to-flaggy in nature. The buff, white and purple shales

constitute the Owk Shale that overlies the Narji Limestone. The Quartzite and the conglomerates of the Banganpalle Formation are considered to have deposited in alluvial setting (Lakshminarayana *et al* 1999) whereas, the Narji Limestone represents the basinal limestone with almost no terrestrial input. The onset of the second cycle is marked by the occasional conglomerate of the Paniam Quartzite. The Koilkuntla Limestone is siliceous and flaggy in nature with pockets of good quality limestone. It gradually passes into purple coloured Nandyal Shale. The cyclic nature, sedimentological structures and lithologic association indicate overall shallow marine depositional environment that range between beach, littoral, tidal-flat and lagoonal environment (Lakshminarayana *et al* 1999).

Age: The Banganpalle Quartzite of the Kurnool Group is diamond bearing and source of the diamonds are considered to be Vajrakarur Kimberlite which has been dated as 1140 Ma (Crawford and Compston 1973). If it is correct then the Kurnool sedimentation is younger than 1140 Ma. Raman and Murthy (1997) proposed the maximum age of 980 Ma (Rb/Sr) and minimum age of 500 Ma (K/Ar) for the shales of the Kurnool Group. Recently, Dongre *et al* (2008) studied mineralogy, major and trace element geochemistry, stable isotope studies of a limestone xenolith found intruded in the Siddanpalli Kimberlite and suggested Late Mesoproterozoic age (older than 1090 Ma) to the Kurnool basin. Limestone xenolith has been considered to be the part of the sedimentary rocks which were available in the vicinity of Kimberlite emplacement. The Bhima and the Kurnool basins were the closest sedimentary rocks inferred to be inter-connected at the time of kimberlite intrusion.

Helically coiled fossils described in this paper have been recovered from the Owk Shale exposed on the eastern part of the hillock $\Delta 1445$ situated in the village Ankireddipalle ($15^{\circ}07':78^{\circ}03'$) and Petnikota ($15^{\circ}5':78^{\circ}4'$) areas of the Kurnool district of Andhra Pradesh. Exposed thickness of the Owk Shale on these spots are about 15 m.

3. Previous studies

King (1872) did not reported the presence of any biotic signatures in the Kurnool sediments, however, dark spotted circular structures were mentioned by him as the cycloid scales of fish. Rajurkar (1963) restudied these structures and compared them with *Fermoria*, now considered, as junior synonym of *Chuarina*. Sharma and Shukla (1999) made a detailed account of carbonaceous remains from the Owk Shale. The carbonaceous remains consisted of compression and impressions belonging

Figure 1. (a) Generalized geological map of the Kurnool basin (after Misra 2011). (b) Lithostratigraphic succession exposed at Ankireddipalle village, Kurnool district, Andhra Pradesh showing Narji Limestone, Owk Shale, and Panium Quartzite. Asterisk indicate the level of the occurrence of carbonaceous fossils. (c) Locality map of the fossils yielding areas in Ankireddipalle village, Kurnool district of Andhra Pradesh.

to Chuarid, Tawuid, Ellypsophysid, Moranid and Beltinid groups. They correlated the Owk Shale with the Bhandar Group of the Vindyan Supergroup and the Halkal Formation of Bhima basin of the peninsular region. Saluja *et al* (1972) reported that microp plankton assemblage consisted of the genera *Leiosphaeridia*, *Lophosphaeridium*, *Grano-marginata*, *Archaeofavosina*, *Protoleiosphaeridium*,

Dictyotidium, *Leiovalia*, *Micrhystridium* and *Priscogalea*. These genera are long ranging in age and were compared to the Bhima assemblage. Bioturbation structures in form of worm burrows were reported by Vijayam (1967) from the Narji Limestone. Occurrence of worm burrows were viewed as evidence of existence of invertebrates and thus the uppermost Proterozoic or Lower Cambrian

Table 1. *Lithostratigraphy of the Kurnool Group of the Cuddapah basin (after Nagaraja Rao et al 1987).*

Kurnool Group	Nandyal Shale	(50–100 m)
	Koilkuntla Limestone	(15–50 m)
	Panium Quartzite	(10–35 m)
	Owk Shale	(10–15 m)
	Narji Limestone	(100–200 m)
	Banganpalle Formation	(10–50 m)
----- Unconformity -----		
Cudd: Srisailam Quartzite		

age was assigned to this formation. Subsequently, worm burrows belonging to *Skolithos* and *Glossi-fungites* assemblage were reported by Arya and Rao (1979) and the Ediacaran age was assigned to the Narji Limestone. Sharma (2008) reported forms like Twitiya discs and *Cyclomedusa* sp. from Panium Quartzite formation that are typical Ediacaran in age.

4. Material and methods

Specimen described in the present paper are recovered from the Owk Shale of the Kurnool Group exposed in south India. Shale samples were macerated with traditional method. Organic residues were mounted on the slides. Specimens were studied under transmitted light on Nikon Eclipse 80i Microscope in BSIP. England Finder co-ordinates are given in parenthesis for each figure. The slides are deposited in the repository of the Birbal Sahni Institute of Palaeobotany Museum bearing number BSIP-14394–BSIP-14407 with statement no. 1301.

5. Systematic palaeontology

Genus: *Obruchevella* Reitlinger, 1948

Obruchevella Reitlinger 1948, p. 78, 1959, p. 21; Luchinina, 1975, p. 29; Kolosov, 1977, p. 73; Yakschin and Luchinina, 1981, p. 29; Kolosov, 1984, pp. 57–58; Song, 1984, p. 181, 183; Yankauskas, 1989, pp. 112–113; Burzin, 1995, pp. 7–9; Nagovitsin, 2000, p. 14.

Volyniella Schepelova and Aseeva in Aseeva, 1974, p. 95; Pashkevichene, 1980, p. 48; Kolosov, 1984, p. 53.

Type species: *Obruchevella delicata* Reitlinger, 1948.

Diagnosis: Empty tubes, sometimes with rare septa coiled into regular cylindrical spiral, sometimes taper or expanding towards ends. In these

spirals tubes, walls usually are tightly joined to one another or in rare cases, they can be loose.

Remarks: Microfossil genus *Obruchevella* has been recorded mainly as permineralized remains in cherts or silicified phosphorites as well as in the dolomites and as macerates residue from shales. Spirals of *Obruchevella* originally were described as foraminifera from the Vendian (Ediacaran) Tinna and Lower Cambrian Sinna Formations of Siberia (Reitlinger 1948, 1959). Later, these fossils were reinterpreted as remains of oscillatoriacean cyanobacteria similar to modern cyanobacterium genus *Spirulina* (Luchinina 1975; Yakschin and Luchinina 1981; Yankauskas 1989). The spiral forms from shales were described independently as genus *Volyniella* (Aseeva 1974) but subsequently merged with genus *Obruchevella* (Yankauskas 1989; Sergeev et al 2012). Besides above-mentioned taxa, many more genera of spiral micro-organisms were described during a half-century study of Proterozoic microfossils, e.g., *Avictuspirulina*, *Glomovertella*, *Glomerula*, *Spirellus*, *Spirillopsis*, *Boruokia*, *Jiangispirellus* and others. However, almost all these taxa can be considered as the degradational or ecological variants of genus *Obruchevella* (table 2).

Contents: *O. blandita*, *O. condensata*, *O. crassa*, *O. cylindrica*, *O. delicata*, *O. ditissima*, *O. exilis*, *O. gigantea*, *O. inviolata*, *O. magna*, *O. meishucunensis*, *O. minor*, *O. minuta?*, *O. parva*, *O. parvissima*, *O. pusilla?*, *O. sibirica*, *O. tungusica*, *O. turukhanica*, *O. uralense* and *O. valdaica*.

Age: Neoproterozoic.

Obruchevella delicata Reitlinger, 1948
Figure 2(a–m)

Obruchevella delicata Reitlinger, 1948, p. 78, 80, pl. I, figures 1, 2; Reitlinger, 1959, p. 21, pl. VII, figures 1–3; Luchinina, 1975, p. 29, pl. XXVII, figures 3–5; Yakschin and Luchinina, 1981, pp. 29–30, pl. IX, figures 1–5; Pyatiletov et al, 1981, figure 1.7; Song, 1984, figure 3.13; Sergeev and Ogurtsova, 1989,

Table 2. Comparative characteristics of the species of genus *Obruchevella* (type specimens).

Name of species	Diagnostic features	Tubes width and spiral outer diameter (µm)	Palaeoenvironmental setting	Repository and type locality	References
<i>O. blandida</i> Schenfil', 1980	Tubes tightly coiled into regular spirals.	2.1–2.2; 18.0–20.0	Open shelf recorded from cherts in dolomites.	Schenfil', 1980, figure 3(a–e); Neoproterozoic, Seryi Klyuch Fm., Enisei Ridge, Russia	Schenfil' (1980)
<i>O. condensata</i> Liu <i>et al.</i> , 1984	Tubes tightly coiled into regular spirals.	3.0–7.0; 10.0–22.0	Tidal flat, recorded from cherts in dolomites.	L16–2–181e; Jiudingshan Fm., Suining County, Jiangsu Province, China.	Liu <i>et al.</i> (1984)
<i>O. crassa</i> KolosoV, 1984	Tubes tightly coiled into regular spirals.	40.0–41.6; 135.0–175.0	Open shelf recorded from shales.	YFSOANUSSR – 87–103; Ediacaran, Kursov Fm., Yakutia, Russia.	KolosoV (1984)
<i>O. cylindrica</i> Tynni and Donner 1980, 1982	Tubes tightly coiled into regular spirals.	4.0–5.0; 50.0–70.0	Open shelf recorded from shales.	GTL200:1; Hailuoto Fm., Borehole No. 2, 52.60 m; Ediacaran, Hailuoto Fm., Finland.	Tynni and Donner (1980, 1982)
<i>O. ditissima</i> Schiptzyn and Yakschin, 1981	Tubes tightly coiled into regular spirals.	18.0–25.0; 110.0–115.0	Open shelf and tidal flats, recorded from cherts in dolomites.	IGG – 309–2219-M/3; Neoproterozoic, Martukhin Fm., Kuznetskii Alatau, Russia.	Yakschin and Luchina (1981)
<i>O. gigantea</i> Golovenok and Belova, 1989	Tubes tightly and loosely coiled into regular spirals.	45.0–55.0; 275.0–360.0	Inertidal and subtidal setting, recorded in silicified phosphorites.	VSEGEI – 671–3–2; Ediacaran, Buton Fm., Middle Ural, Russia.	Golovenok <i>et al.</i> (1989)
<i>O. inviolata</i> KolosoV, 1984	Tubes loosely coiled into regular spirals.	27.0–47.0; 200.0–230.0	Open shelf, recorded from shales.	YFSOANUSSR – 87–99; Ediacaran, Kursov Fm., Yakutia, Russia.	KolosoV (1984)
<i>O. magna</i> Golovenok and Belova, 1989	Tubes loosely coiled into regular spirals.	28.0–37.0; 135–175	Inertidal and subtidal setting, recorded in silicified phosphorites.	VSEGEI – 671–2; Ediacaran, Buton Fm., Middle Ural, Russia.	Golovenok <i>et al.</i> (1989)
<i>O. meishucumensis</i> Song, 1984 Pl. XIX, figure 7, Text-figure 42(b)	Tubes loosely coiled into large regular spirals.	20.0–22.0; 100.0–120.0	Inertidal to supratidal facies, recorded in silicified phosphorites.	Song, 1984, figure 3.7, M4–38–32; Lower Cambrian, Yuhucun Fm., China.	Song (1984)
<i>O. minor</i> Zhang, 1984 Text-figure 42(c)	Tubes coiled into regular spirals.	3.5–5.5; 10.0–19.5	Inertidal to supratidal facies, recorded in silicified phosphorites.	Ediacaran, Doushantuo Fm., China.	Zhang (1984)

Table 2. (Continued)

Name of species	Diagnostic features	Tubes width and spiral outer diameter (μm)	Palaeoenvironmental setting	Repository and type locality	References
<i>O. minuta</i> ? Allison, 1989 in Allison and Awramik, 1989	Tubes tightly coiled into small regular spirals.	~ 0.8 ; 7.0 – 8.0	Intertidal to supratidal facies, recorded in cherts from dolomites.	BC75 44–9; Neoproterozoic, Tinder Group, Alaska, USA.	Allison and Awramik (1989)
<i>O. pusilla</i> ? Golovenok and Belova, 1983	Tubes loosely coiled into regular spirals.	1.0–1.65; 4.0–4.5	Intertidal to peritidal recorded in cherts.	VSEGEI – 62-e; Ediacaran, Valyukhta Fm., Patom Uplift, Russia.	Golovenok and Belova (1983)
<i>O. sibirica</i> Reitlinger, 1959	Tubes tightly coiled into big regular spirals.	14.0–17.0; 57.0–58.0	Intertidal to supratidal facies, recorded in dolomites.	GINPC – 3434/38; Upper Cambrian, Siberia, Russia.	Reitlinger (1959)
<i>O. tungusica</i> Pyatiletov, 1986	Flattened ribbon-like filaments, loosely coiled.	14.0–16.0; 18.0–20.0	Intertidal recorded from shales.	IGG – not provided; Ediacaran, Vanavara Fm., Katanga Saddle, Russia.	Pyatiletov (1986)
<i>O. turukhanica</i> Hermann, 1981	Tubes (trichomes) coiled into loose spirals.	4.0; 8.0–10.0	Subtidal middle shelf, recorded from shales.	IGGP – 49a/3, Neoproterozoic, Miroedikha Fm., Turukhansk Uplift, Russia.	Hermann (1981)
<i>O. uralense</i> Yankauskas, 1980	Tubes very loosely coiled into regular spirals.	3.5–4.5; 7.0–9.0	Intertidal, recorded in cherts from dolomites.	LitNIGRI – 16–25–9/1; Neoproterozoic, Inzer Fm., South Ural, Russia.	Yankauskas (1980)
<i>O. valdaica</i> (Schepeleva ex msc.), Asseva, 1974	Flattened tubes very loosely coiled into spirals.	11.8–19.0; 46.0–170.0	Intertidal, recorded from shales.	IGS NAS – 242/1; Ediacaran, Yaryshev Fm., Podolia, Ukraine.	Asseva (1974)

Figure 2. Helically coiled microfossils recorded from the Owk Shale of the Kurnool Group. In this and all following figures, slide catalogue number for the Birbal Sahni Institute of Palaeobotany Museum (BSIP) and England Finder coordinates for each illustrated fossil is given in brackets. Note the tightly coiled structure of each specimen. Except **b** and **j**, all are incomplete specimen. (**a–m**) *Obruchevella delicata* Reitlinger (**a**) (BSIP-14404; U41/2), (**b**) (BSIP-14403; R54/3), (**c**) (BSIP-14394; G41), (**d**) (BSIP-14407; R33/2), (**e**) (BSIP-14407; W45/3), (**f**) (BSIP-14400; D44), (**g**) (BSIP-14401; O69), (**h**) (BSIP-14405; N66/4), (**i**) (BSIP-14399; V44/4), (**j**) (BSIP-14394; O68), (**k**) (BSIP-14397; Q56/2), (**l**) (BSIP-14398; K53/2), (**m**) (BSIP-14394; F66). Scale bars = 50 μm for **i**; 20 μm for **a–f**, **h**, **j–m**; 10 μm for **g**.

Figure 3. Helically coiled microfossils recorded from the Owk Shale of the Kurnool Group. Note the loosely coiled helical structure of each specimen. (a–j) *Obruchevela parva* Reitlinger, 1959 (a) (BSIP-14400; J47), (b) (BSIP-14405; K62), (c) (BSIP-14400; R57), (d) (BSIP-14397; R45/4), (e) (BSIP-14399; V31), (f) (BSIP-14401; Q42/2), (g) (BSIP-14396; K50), (h) (BSIP-14397; P41), (i) (BSIP-14395; Q36), (j) (BSIP-14396; P55). Scale bars for a = 50 μm ; b, d, e, g–j = 20 μm and c, f = 10 μm .

Figure 4. Helically coiled microfossils recorded from the Owk Shale of Kurnool Group. Note very loosely coiled helical structure of the specimens. (a–b) *Obruchevela minor* Zhang (a) (BSIP-14401; K44/3), (b) (BSIP-14405; X33/4).

pl. I, figure 4; Golovenok and Belova, 1989, pp. 193–194, figures 1e–13; Sergeev, 1992a, pp. 89–90, pl. XXV, figures 7a, 7b; Mankiewicz, 1992, figures 6.1–6.5, 8.1–8.7; Prasad *et al*, 2005, pl. 10, figures 7, 11, pl. 11, figure 11; Prasad, 2007, pl. 1, figures 4, 7, 8, 14, 18.

Stratum typicum: Lower Cambrian, Sinna Formation, Patom Uplift, Russia.

Description: Empty tubes, sometimes with rare septa coiled into regular cylindrical spiral do not

Figure 5. (a–d) *Obruchevela valdaica* (a) (BSIP-14401; 62/1), (b) (BSIP-14403; F41/2), (c) (BSIP-14402; K47/1), (d) (BSIP-14406; J66/3). Scale bars = 20 μm for b, c, e, f; 10 μm for a and d.

taper towards ends. In these spiral tube walls usually tightly joined to one another or can be loose. Some of the spirals may twist in other direction than main spiral direction, a feature which may be a result of post-mortem uncoiling. Total 13 specimens recorded. Spiral outer diameter is 18–44 μm , spiral length is up to 141 μm .

Remarks: Tubes of *Obruchevelia* can be either sheaths or trichomes transformed into empty structures as a result of diagenetic alteration. Rarely septa could survive post-mortem degradation and rarely observed in case of some *Obruchevelia* specimens.

Age and distribution: Ediacaran (Vendian): Tinna Formation, Patom Uplift, Siberia; Nagod Limestone Formation, India; Lower Cambrian: Sinna Formation, Patom Uplift, Siberia; Chulaktau Formation, South Kazakhstan; Yuhucun Formation, China; Burgess Shales, Canada.

Obruchevelia parva Reitlinger, 1959, emend. Golovenok and Belova, 1989, emend. Burzin, 1995 Figure 3(a–j)

Obruchevelia parva Reitlinger, 1959, p. 21, pl. VI, figures 1, 2; Kolosov, 1977, pp. 73–74, pl. VI, figure 1; 1982, pl. XVI, figures 1a, 16; Cloud *et al.*, 1979, pp. 87–89, figures 5J–5K; Yakschin and Luchinina, 1981, p. 30, pl. X, figures 1–3; Pyatiletov *et al.*, 1981, figure 1.11; Golovenok and Belova, 1983, p. 1464, figures 1b–1d; Song, 1984, p. 183, figures 3.1–3.3, 3.8, 3.9; Sergeev, 1989, pl. 2, figures 1–3, 5, 6, 8; Sergeev and Ogurtsova, 1989, pl. I, figures 1–3, 5–9, 12; Golovenok and Belova, 1989, p. 193, figures 16–1b; Sergeev, 1992a, p. 89, pl. XXIV, figures 5, 6, 11, pl. XXV, figures 1a, 16, 2, 3, 5, 6a, 66; Burzin, 1995, pp. 10–11, 13, pl. I, figures 1–3, 4A, pl. III, figure 1; Prasad *et al.* 2005, pl. 10, figures 4, 12, pl. 11, figure 9; Prasad, 2007, pl. 1, figures 3, 6, 15 (for complete synonymy, see Burzin 1995 and Golovenok and Belova 1989).

Stratum typicum: Ediacaran (Vendian), Tinna Formation, Patom Uplift, Russia.

Description: Empty tubes, sometimes with rare septa coiled into regular cylindrical spiral do not taper towards ends. 10 specimens recorded. The tubes diameter ranges from 7 to 8 μm , spiral outer diameter is 18–60 μm , spiral length is up to 157 μm .

Remarks: Numerous emendations of *Obruchevelia* species, especially of *O. parva* and *O. delicata*, in our opinion, only complicated the situation of the

fossil cyanobacterium genus. Therefore, we followed the original description by Reitlinger (1948, 1959) with measure corrections done by Golovenok and Belova (1989) and our studies are based on the type material deposited in GINPC Moscow, Russia.

Age and distribution: Widely distributed in Ediacaran (Vendian) and Lower Cambrian silicified and organic-walled assemblages.

Obruchevelia minor Zhang, 1984
Figure 4(a,b)

Stratum typicum: Late Sinian, Toushantou Formation, Western Hubei, China.

Description: Tubular filaments, spirally coiled and helically twisted. Helix straight to slightly curved along its length. Coiling loose, adjacent coils not touching, filaments non-septate. The diameter ranges from internal diameter 4 to 9 μm , spiral outer diameter is 10 to 19.5 μm , spiral length is up to 66 μm . Two specimens recorded (figure 4a and b). For figure 4(a), outer diameter of coil is 20 μm , cross sectional diameter of tube is 4 μm , length of the specimen is 68 μm . For figure 4(b), outer diameter of coil is 35 μm , cross sectional diameter of tube is 8 μm , length of the specimen is 98 μm .

Remarks: Zhang (1984) distinguished *O. minor* from the *O. parva* and *O. delicata* on the basis of its smaller size. Moreover, the spirals are loosely coiled and adjacent coils are not touching in the case of *O. minor*. In Kurnool specimens, one specimen (figure 4a) lie exactly in the size range described by Zhang (1984). Second specimen is slightly large but due to its loosely coiled habit we placed this specimen also in *O. minor*.

Age and distribution: Late Sinian, Toushantou Formation, Western Hubei, China.

Obruchevelia valdaica (Schepeleva ex msc.), Aseeva, 1974
Figure 5(a–d)

Volyniella valdaica: Aseeva, 1974, p. 96 (part), pl. 1, figure 1, nonfigures 2, 3; 1976, pl. XVIII, figure 1, nonfigures 3–5; 1983, pl. VI, figure 12, nonfigure 11; Aseeva in Velikanov *et al.* 1983, pl. XVII, figures 10, 11, non pl. XII, figure 4; Aseeva in Volkova, 1985, pl. LVI, figure 4, nonfigure 5; Hermann, 1985, p. 148, pl. LXXIV, figures 3, 6, 7; Burzin, 1995, pp. 19–23, pl. II, figures 1–5, pl. III, figure 2.

Non *Volyniella valdaica* Aseeva: Ragosina, 1984, pl. I, figure 8; Ragosina and Sivertseva, 1985, pl. LVIII, figures 22–23; Pyatiletov, 1986, pl. V, figure 5.

Obruchevella valdaica: Yankauska *et al.*, 1989, p. 115, pl. L, figures 1, 2; Hofmann and Jackson, 1994, figures 11.18–11.22; Prasad and Asher, 2001, pl. 9, figure 9; Prasad *et al.*, 2005, p. 54, pl. 10.5, 6; Prasad, 2007, pl. f, figures 5, 17; Shukla *et al.*, 2006, p. 64, pl. I, figure 19.

Leiotrichoides sp.: Ragosina and Sivertseva, 1985, pl. LX, figure 9.

Spiromorpha sp.: Timofeev, 1973, pl. II, figure 10, pl. XIV, figures 7–9; non pl. XII, figure 2.

Stratum typicum: Yaryshev Formation, Podolia, Ukraine.

Diagnosis: Tubular filaments, spirally coiled and helically twisted in one or two whorls tightly compressed arrangements, coils are concentric form irregular circular structures. Trichome non-septate. In all the specimens in our collection the central part of the coiled portion is absent. The outer diameter of helix ranges from 48 to 87 μm , the mean helix diameter is 61.9 μm and width of the filament ranges from 8–16 μm ; mean filament width is 11.7 μm . Four specimens are recorded.

Remarks: The spiral forms recovered from shales were described independently as genus *Volyniella* (Aseeva 1974) and subsequently merged with genus *Obruchevella* (Yankauskas 1989; Sergeev *et al.* 2011). However, Burzin (1995) has argued against this synonymy and suggested to keep *Volyniella* as an independent genus. But considering all variations within *Obruchevella* species, including post-mortem alterations, we do not agree to Burzin and follow revision proposed by Yankauskas (1989) and Sergeev *et al.* (2012, in press).

Age and distribution: Ediacaran, Yaryshev Formation, Podolia, Ukraine; Vendian, Mogilev-Podolsk Group of Volyno-Podolya, Moldavia, Redinko horizon of the north-west of the Archangelsk region; late Mesoproterozoic/earliest Neoproterozoic Thule Supergroup, Northwest Greenland; late Mesoproterozoic/earliest Neoproterozoic Baylot Supergroup, Canada. Terminal Neoproterozoic–Lower Cambrian Buxa dolomite lesser Himalaya, India; Bhander Group, Vindhyan Supergroup, India.

6. Discussion

Based on morphological and ecological characteristics helically coiled microfossils are divided in four broad categories.

- *Obruchevella*: It is a filamentous form constituted of isodiametric tubular sheath with open ends

that coiled to form a cylindrical helix. Originally tightly coiled mineralized forms were assigned to this genus including sheathed and/or unsheathed forms. Subsequently, loosely coiled (Zhang 1984) sheathed and/or unsegmented forms (Song 1984) and non-mineralized specimens (e.g., Pyatiletov *et al.* 1981) were also included in this group. Preserved cellular remains are also recorded (Song 1984; Knoll and Ohata 1988). Morphologically these forms are very similar to extant cyanobacterial group *Lyngbya–Phormidium–Plectonema* (LPP), however, generally it has been compared with modern *Spirulina*. Burzin (1995) proposed certain forms such as *Volyniella* which were tubular filamentous, without any cellular structure and terminally closed. Burzin (1995) considered it as a trichomatous form while in having septa whose cellular structure cross walls were selectively destroyed on burial leaving outer sheath. Similar degradational changes have been noted in most of the modern cyanobacteria. Subsequently, *Volyniella* has been merged with *Obruchevella* (Sergeev *et al.* 2012, in press).

- *Boruokia*: It is a trichomatous form where no sheath has been observed and naked cells constituted helically coiled morphology. Cells are disc shaped or cylindrical and are not separated by deep constrictions. Modern *Oscillatoria* and *Spirulina* have similar morphological features.
- *Grypania*: It is a solitary helically coiled megascopic carbonaceous fossil which has taeniate thallus with rounded termination. No internal cellular structure has been observed. These are recorded as compression or impression forms and in some cases spirals are uncoiled. Their characteristics are discussed in detail (Walter *et al.* 1990; Kumar 1995; Sharma and Shukla 2009a, 2009b). Morphologically these are similar to *Arthrospira* and *Spirulina*.
- *Spirillopsis*: Burzin (1995) established *Spirillopsis* as a new group of helically coiled microfossils. It is mineralized coiled form with thin tubular sheath containing pyrite grains. These grains are arranged in chain or in clusters completely filling the entire sheath. Sometimes, during preservation, spirals are uncoiled and flattened. It is similar in morphological and ecological perspective with modern benthic filamentous sulfur bacteria belonging to Beggiatoaceae.

Obruchevella and its different species are mostly recorded from the sediments that were deposited close to Precambrian–Cambrian boundary successions. The species of *Obruchevella* are distinguished from other microfossils due to their distinctive coiled shape.

The Kurnool helically coiled microfossils have been taxonomically described. Their ecology,

preservation, affinity and age connotation is being discussed in the following sections.

Ecology: *Obruchevelia* is known from cherts, shale, limestone, dolomite and phosphorite and its excellent undistorted preservation as an organic walled microfossil suggests autochthonous burial (Burzin 1995). It has been recorded from the open shelf tidal flat environment ranging from supratidal, intertidal and to subtidal. In some of the specimens, occurrences of pyrite crystals have been demonstrated by Sergeev (1992b) in the sheath of some of the *Obruchevelia*. This could be seen in the light that some modern cyanobacteria which are occasionally photosynthesized anaerobically have sulphur grains in their cells (Stanier *et al* 1981). Many strains of cyanobacteria are capable of doing anoxygenic bacterial-type photosynthesis and as a result sulphide is oxidized to elemental sulphur which was observed as refractile granules either free in the medium or adhering to the cyanobacterial filaments (Padan and Cohen 1982). Calcareous forms found in *Obruchevelia* suggest benthic mode of life, like some modern cyanobacteria (Burzin 1995).

Preservation: The genus has been recorded from varied lithologies (chert, shale, limestone, dolomite and phosphorite). Only the tubular sheath with no traces of trichomes inside may be preserved as an organic walled form. Silicified microfossils, calcareous algae, and phosphatized remains are known in mineralized forms. In the Kurnool sediments, *Obruchevelia* are preserved as carbonaceous remains in the Owk Shale and similar type of preservation has been reported from shales. *Obruchevelia* species recorded from Yunan Province, China (Song 1984), have cross partitioning and preserved with or without sheaths. Song (1984) opined that the hollow sheaths of *Obruchevelia* are found in two ways either the cross-partitioning of trichome lost or in the filament the entire trichome degraded. Degradation might play a role to change the shape of the helix. Change in the distance between the coil, compactness of the helix and bending of the axis of helix are the resultant of post-mortem changes (Song 1984). One of the exceptional preservation of *O. cf. gigantea* was reported by Golovenok *et al* (1990) from the Parsha Formation of Yakutia as compressions on shales surfaces like *Chuarina* and some other carbonaceous remains are found in Meso-Neoproterozoic successions.

Affinity: Spirals of *Obruchevelia* originally were described as foraminifera from the Vendian

(Ediacaran) Tinna and Lower Cambrian Sinna Formations of Siberia (Reitlinger 1948, 1959). Later, these fossils were reinterpreted as remains of oscillatoriacean cyanobacteria similar to modern cyanobacterium genus *Spirulina* (Luchinina 1975; Yakschin and Luchinina 1981; Yankauskas 1989; see Peel 1988).

It has been suggested (Cloud *et al* 1979) that the size of the *Obruchevelia* varies with the age of the successions in which they are found. The *Obruchevelia* larger than *O. parva* seems to be confined to the relatively younger horizons, as in the Cambrian and Ordovician rocks of former Soviet Union and North America. He concluded that the larger species of *Obruchevelia* are of the Cambrian and younger age and *O. parva* is limited to the Ediacaran age. Mankiewicz (1992), in a comprehensive work, showed that the size of *Obruchevelia* species has nothing to do with the age of the strata, and the species of one stratigraphic unit spanned the entire size range. Peel (1988) described the phosphatized helically coiled microfossils *Spirellus*, *Obruchevelia*, and a new genus *Jiangispirellus* from the Lower Cambrian of north Greenland. All are helical forms and former two are larger than most *Obruchevelia* species but occupy the same ecological niche. Therefore, the distribution and size parameters of the *Obruchevelia* are independent of ecological niche and age however, most of them are confined to the Ediacaran and younger sedimentary succession.

Dongre *et al* (2008) proposes Mesoproterozoic age for the basin which contradicts of what is inferred from the available palaeobiological data. In the present situation, the occurrence of *Obruchevelia* is important to ascertain the age of the basin as it is considered as typical Vendian marker genus. Previously, some workers attempted to ascertain the age of the basin on the basis of assemblage recovered from the basin and correlated the Owk Shale with the Bhander Group of Vindyan Supergroup and the Halkal Formation of Bhima basin (Salujha *et al* 1972; Sharma and Shukla 1999). Salujha *et al* (1972) reported that varied microplankton assemblage consisted of the genera that are long ranging and biostratigraphically nonpotential. Varied types of carbonaceous remains were reported by Sharma and Shukla (1999). Occurrence of *Tawuia* in their assemblage indicates the Neoproterozoic age of the Owk Shale. In the present study, four distinct species of *Obruchevelia* are recorded. Among them *O. valdaica* is the largest in terms of size range. All four species have known occurrences from the Late Neoproterozoic to Early Cambrian. Thus, the age did not have any effect on the size of *Obruchevelia* species. While analyzing the Archaean and Proterozoic biota, Knoll (1996) stated that "Although older Neoproterozoic specimens of *Obruchevelia*

are known, Vendian-Lower Cambrian came of this genus is a real phenomenon without adequate palaeobiological explanation”.

7. Conclusion

- Present work records distinct species of helically coiled microfossil *Obruchevella*, viz., *O. delicata*, *O. parva*, *O. minor* and *O. valdaica* that made their appearance in Ediacaran as well as in Lower Cambrian strata.
- Previous report of occurrence of *Tawuia* in the Owk Shale suggests the Neoproterozoic age of the Owk Shale.
- Occurrence of *Obruchevella* in the Owk Shale together with worm burrows in the underlying Narji Limestone and Ediacaran forms in overlying Panium Quartzite collectively indicate Ediacaran age close to the Cambrian for the Owk Shale as well as for the Kurnool Group.

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