Research paper

Largest Ediacaran discs from the Jodhpur Sandstone, Marwar Supergroup, India: Their palaeobiological significance

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A B S T R A C T

Ediacaran discs from the Jodhpur Sandstone of the Marwar Supergroup, Rajasthan, exhibit a wide size ranging from a few millimetres to 75 cm in diameter. Exceptionally large size of the discs in these rocks represent the largest reported so far from any Ediacaran assemblage. Although, larger medusoid discs have been reported from USA, they are from the middle Cambrian and even younger rocks. Presence of microbial mats and weed-like structures with well preserved hold fasts and horizontal rhizome-like structures in association with some of these large-sized discs support their animal affinity, which probably feed on this weed-like vegetation. This association also supports their benthic habitat. Unlike the general trend of sudden increase in size of organisms in Ediacaran period and further decrease in size during Cambrian, these discs continued increasing in size in Cambrian also.

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1. Introduction

Discoidal fossils are the most common component and were the first described elements of the Ediacaran biota. They are also the youngest Ediacaran fossils in terms of age. The Ediacaran period (635–542 Ma) witnessed an important evolutionary episode prior to the “Cambrian Explosion” and revealed information about early macroscopic evolution of multicellular complex life (Xiao and Laflamme, 2008; Laflamme et al., 2013). Recent studies indicate that Ediacaran fossils dominated by discs epitomize a phylogenetically diverse biosphere probably including animals, protists, algae, fungi and others. In general, cnidarian affinity is considered for most of these Ediacaran discs. Their simple ecology is dominated by epibenthic osmotrophs, deposit feeders and grazers (Glaessner, 1984; Gehling, 1991). Very recently, a moderately diverse and heterogeneous Ediacaran discoidal assemblage has been reported from the Jodhpur Group (Srivastava, 2012c). Morphological diversity among these discs is biologic or governed by taphonomic interplay has been discussed in that paper. Gigantism or sudden increase in size of the Jodhpur discs and its significance are being discussed in present paper.

The Neoproterozoic (1000–542 Ma) has been considered as an eventful period marked by rapid movement of crustal blocks and changes in continental configurations (Meert, 2003). It was also a period of changes in global climatic conditions and prepared the ground for biological changes and triggers for the stimulation and proliferation of multicellular life (Hoffmann et al., 1998; Meert and Leiberman, 2004, 2008; Santosh et al., 2013). Extreme climatic conditions and snowball-Earth have also been associated with this period. The northwestern Indian Craton also known as Aravalli Craton is one of the excellent regions to study the Neoproterozoic events as a well preserved geological record from 1 Ga to Pre-cambrian—Cambrian transition. At 1 Ga the Delhi orogeny marked as the collision between Aravalli Craton and an unknown craton in the west is known as Marwar Craton. Extensive felsic magmatism, including arc magmatism of Cryogenian age has been recorded from this region (Dharma Rao et al., 2012). The Malani magmatism forms the basement for the shallow tidal sedimentary sequence of the Marwar Supergroup (Ediacaran—Cambrian age). This shallow basin extends E–W and shows sedimentation under subtidal
conditions indicated by predominant arenaceous facies. In the conventional palaeogeographic reconstructions, India—Australia and Antarctica have been shown as coherent tectonic trio during pre-Rodinian times (Pandit, 2010).

The Marwar Supergroup (previously known as the Trans-Aravalli Vindhysans) in western Rajasthan, attains a thickness of about 1000 m (Pareek, 1984). The supergroup’s further division in stratigraphic order is: Jodhpur, Bilara and Nagaur groups (Fig. 1, Table 1). Pareek (1981, 1984) has subdivided the Jodhpur Group into the Pokaran boulder bed, the Sonia Sandstone and the Girbhaker Sandstone, but later on Chauhan et al. (2004) have merged Sonia Sandstone and Girbhaker Sandstone with the Jodhpur Sandstone. Hence, the Jodhpur Group is now considered to be further divided into the Pokaran boulder bed and the Jodhpur Sandstone. This stratigraphic classification has been adopted by number of workers (see Raghav et al., 2005; Kumar and Pandey, 2009, 2011) and it is being followed in the present paper also. Since last one decade, the Marwar Supergroup specifically the Jodhpur Group has emerged as one of the best repositories for Ediacaran body fossils (Raghav et al., 2005; Kumar and Pandey, 2009; De and Prasad, 2012; Srivastava, 2012c). The lithology of the supergroup can be represented by siliciclastic Sandstone, siltstone, shale and carbonates. Some significant reports on various aspects like microbial mats (Sarkar et al., 2004, 2005, 2008, 2012; Samanta et al., 2011; Parihar et al., 2012), ichnofossil (Kumar and Pandey, 2008, 2009, 2010); an Ediacaran/Cambrian boundary marker form *Treptichnus pedum* and *Priapulid* worm-like fossils, which are considered to be the organisms responsible for the construction of pedum burrows (Srivastava, 2012a,b) and mega-algal fossils (Kumar et al., 2009; Srivastava, 2011) from the supergroup have drawn attention of international scientific community.

### Table 1

<table>
<thead>
<tr>
<th>Supergroup</th>
<th>Group</th>
<th>Formation</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconformity</td>
<td>Marwar Supergroup</td>
<td>Bap boulder beds</td>
<td></td>
</tr>
<tr>
<td>Nagaur Group</td>
<td>Tunklian Sandstone</td>
<td>Brick red Sandstone, siltstone &amp; red claystone</td>
<td></td>
</tr>
<tr>
<td>Nagaur Sandstone</td>
<td>Brick red Sandstone, siltstone &amp; red and green clay beds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilara Group</td>
<td>Pondlo dolomite</td>
<td>Cherty dolomitic limestone</td>
<td></td>
</tr>
<tr>
<td>Gotan limestone</td>
<td>Interbedded dolomite &amp; limestone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dhanapa dolomite</td>
<td>Dolomitic limestone with chert lenses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jodhpur Group</td>
<td>Jodhpur Sandstone</td>
<td>Reddish yellow gritty Sandstone with reddish brown clay beds</td>
<td></td>
</tr>
<tr>
<td>Pokaran boulder bed</td>
<td>Conglomerate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malani igneous complex/Aravalli rocks</td>
<td>(780–681 Ma)</td>
<td></td>
<td></td>
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</table>

Figure 1. Lithostratigraphy of the Marwar Supergroup, Rajasthan (after Srivastava, 2012a).
Figure 2. Geological map of the Marwar Supergroup (after Raghav et al., 2005).

Figure 3. Exceptionally large-sized Ediacaran discs, in association with macroalga-like structures (exhibited by drawing also) from the Jodhpur Sandstone Formation, Marwar Supergroup in Sursagar area, Jodhpur.
Figure 4. Variable morphologies shown by large-sized Ediacaran discs from the Jodhpur Sandstone.
Age of the Marwar Supergroup is considered younger than 681 Ma, as it unconformably lying above the Malani Igneous Suite (dated 780–681 Ma, Pareek, 1984; Rathore et al., 1999). Malone et al. (2008) analyzed detrital zircon from the Girbhaker and Jodhpur Sandstone, and suggested age range between 800 and 900 Ma. Earlier there was no evidence regarding the upper age limit except the belief that it is continuation of Vindhyan Supergroup (Heran, 1932; Shrivastava, 1971), but recently McKenzie et al. (2011) have provided dates for the base of Nagaur Sandstone. Recently reported Ediacaran fossils from the Jodhpur Sandstone (Raghav et al., 2005; Kumar and Pandey, 2009; De and Prasad, 2012; Srivastava, 2012c), trilobite trace fossils (Kumar and Pandey, 2008, 2010) and Priapulid worm-like fossils and Treptichnus pedum; these dimensional horizontal burrows considered to be Precambrian/Cambrian boundary marker (Srivastava, 2012a,b) from the Nagaur Sandstone, suggest Ediacaran to Cambrian age for the Marwar Supergroup. The boundary was earlier suggested in the Bilara Group, on the basis of isotope data (Pandit et al., 2001; Mazumdar and Strauss, 2006).

Earlier, deposition of the Pokaran boulder beds was suggested in glacial or fluvo-glacial environmental conditions, corresponding to global Varangerian ice age 630–580 Ma (Shrivastava, 1971; Kumar, 1999; Chauhan et al., 2004). Basu (2009) inferred that the Pokaran boulder bed can be correlated with the global Sturtian glaciations and that products of Marinoan glaciation have not been preserved in western India. On the other hand Kumar et al. (1997) did not find any glaciogenic sediments and any evidence of Varangerian glaciation from the Indian subcontinent. Since boulders are well rounded and diamictites are not reported, author also has reservation in considering glacial origin for these boulders. On the basis of litho- and chemostratigraphy, Pandey and Bahadur (2009) inferred that the Ediacaran—early Cambrian basin fills consist of siliciclastic sediments in India and Pakistan.

The Jodhpur Group exhibits moderately diversified Ediacaran fossil assemblage from the coarse to fine grained, pink to buff coloured siliciclastic Sandstone in Sursagar area and chocolate coloured shale in Artiya Kalan area belonging to the Jodhpur Sandstone Formation in Jodhpur district, western Rajasthan (Fig. 2). Earlier, Ediacaran fossils have also been reported from this stratigraphic horizon (Raghav et al., 2005; Kumar and Pandey, 2009; Srivastava and Mathur, 2010; De and Prasad, 2012; Srivastava, 2012c).

The sediments of the Marwar Supergroup are the result of a wide-spread marine transgression over Malani Igneous Suite (Kumar et al., 1997). Shrivastava (1971, 2005) suggested shallow water non-marine to marine, fine to coarse grained mixed arenaceous-argillaceous and calcareous facies for the Jodhpur Sandstone. Pandey and Bahadur (2008) suggested that siliciclastic sediments around Jodhpur have been mainly deposited in shallow water above fair-weather wave base both in marine and non-marine environments. In Sursagar area about 7 km from the Jodhpur, from where the present fossils have been reported (N26°19’53.9”, E72°59’48.2”; N26°19’54.9”, E72°59’44.4”) is the middle part of Jodhpur Sandstone, which has also been referred to as the Sonia Sandstone, earlier by Pareek (1984) and a few other workers (Fig. 2). The upper part of Sonia Sandstone (which is probably the horizon of present study) represents marine environment of deposition. This Sandstone horizon displays parallel bedding, deformational bedding, cross beddings with low angle discordances, microbial mats and Ediacaran body fossils. These sediments are considered to be beach to coastal sand deposits formed in a moderate to high energy, shallow marine setting (Raghav et al., 2005; Kumar and Pandey, 2009).

2. Method and results

In present assemblage the discs are preserved on bedding surface as three dimensional body fossils with morphological features well comparable to the fossil medusoids of the other established Ediacaran assemblages. Consistency in their morphology; like smoothness and crenulations on margins and very prominently preserved inner circular body (Figs. 3A,B and 4A,B,C,F,G) with sheath or outer covering-like structures (Fig. 4C,D,F), rule out the possibility of inorganically produced structures. They cannot be compared with mud or sand volcano, water escape structure or Microbially Induced Sedimentary Structures (MISS). Specimen shown in Figs. 3C and 4B,C,F,G, may possibly be the oral side of the organism comprising mouth/anus like structure represented by centrally or eccentrically located inner circular body.

Maximum size of the Ediacaran discs measured in present assemblage far exceeds the size of discs reported earlier. Maximum diameter of Ediacaran disc so far, reported from the Indian subcontinent is 13 cm. Globally, 22 cm is the maximum size of discs reported from the South Australia (Wade, 1972). The diameter of discs in present assemblage measured up to 75 cm (Fig. 3C), which is probably the largest size recorded so far from any discoidal assemblage of Ediacaran period (Table 2). Size distribution patterns of the Ediacaran discs in present assemblage show the clear pattern of clustering near 2–15 cm (Fig. 6) and very little number of exceptionally large-sized specimens (Fig. 7).

A very significant aspect of the Jodhpur Ediacaran discs is their association with macroalgae-like fossils with well preserved hold fasts and horizontal rhizome-like structures supporting their benthic habitat, clearly shown in Fig. 5A and B.

Table 2

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Diameter Age</th>
<th>Locality</th>
<th>Author</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>10.20 Ediacaran</td>
<td>Pound Group, South Australia</td>
<td>Gehling, 1987</td>
</tr>
<tr>
<td>2</td>
<td>60.00 Ediacaran</td>
<td>Southwest Great Britain</td>
<td>Hagadorn and Waggoner, 2000</td>
</tr>
<tr>
<td>3</td>
<td>178.00 Ediacaran</td>
<td>Innerly Member, Norway</td>
<td>Farmer et al., 1992</td>
</tr>
<tr>
<td>4</td>
<td>200.00 Ediacaran</td>
<td>South Australia</td>
<td>Wade, 1972</td>
</tr>
<tr>
<td>5</td>
<td>35.50 Ediacaran</td>
<td>China and Australia</td>
<td>Zhu et al., 2008</td>
</tr>
<tr>
<td>6</td>
<td>150.00 Ediacaran</td>
<td>Sweden</td>
<td>Jensen et al., 2002</td>
</tr>
<tr>
<td>7</td>
<td>150.00 Ediacaran</td>
<td>Mistaken Point, Newfoundland</td>
<td>Misra, 1971; Anderson and Morris, 1982; Clapham and Narbonne, 2000</td>
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<tr>
<td>8</td>
<td>50.00 Ediacaran</td>
<td>White Sea, Russia</td>
<td>Ferguson and Simony, 1991</td>
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<td>9</td>
<td>160.00 Ediacaran</td>
<td>British Columbia</td>
<td>Narbonne and Hofmann, 1987</td>
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<td>10</td>
<td>18.00 Ediacaran</td>
<td>Werneck Mountain, Canada</td>
<td>Clapham and Narbonne, 2000</td>
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<tr>
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<td>220.00 Ediacaran</td>
<td>Canada</td>
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<td>Krol Formation, India</td>
<td>Mathur and Shanker, 1990</td>
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<td>De, 2003</td>
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<td>17.00 Ediacaran</td>
<td>Marwar Supergroup, India</td>
<td>De and Prasad, 2012</td>
</tr>
<tr>
<td>17</td>
<td>750.00 Ediacaran</td>
<td>Marwar Supergroup, India</td>
<td>Present assemblage</td>
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<td>18</td>
<td>950.00 Middle Cambrian</td>
<td>Elk Mound Group, USA</td>
<td>Hagadorn et al., 2002</td>
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<tr>
<td>19</td>
<td>660.00 Middle Cambrian</td>
<td>Potsdam Group, Canada</td>
<td>Hagadorn and Belt, 2000</td>
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</table>


3. Discussion and conclusion

Globally, the medusoid discs are the most common fossils among Ediacaran fossil assemblages. They exhibit a wide size range from few millimetres to several centimetres. Size distribution patterns of the Ediacaran discs in present assemblage shown in scatter diagram, clear concentration near 2–15 cm (Fig. 6) and very little number of exceptionally large-sized specimens in bar-diagram (Fig. 7). In India, Ediacaran discs have been reported from the Lesser Himalayan region (Mathur and Shanker, 1990; Shanker et al., 2004); from the Maihar Sandstone, and Bundi Hill Sandstone of the Vindhyan Supergroup (De, 2006; Srivastava, 2006, 2012d; respectively) and from the Jodhpur Sandstone Formation of the Marwar Supergroup in western Rajasthan (Raghav et al., 2005; Kumar and Pandey, 2009; Srivastava, 2011, 2012c).

Figure 5. Photographs of macroalgal Ediacaran fossil from the Jodhpur Sandstone showing megascopic algae like morphology with horizontal rhizomes and hold fast like features, indicating benthic habitat.
As far as affinity of these discs is concerned, opinions are diverse. Hagadorn and Bottjer (1997) considered them to be the multicellular or multinuclear and not the colonies of single celled organisms. Zhuralev (1993) proposed them as giant protists, Seilacher (1989, 1992) considered them as organisms which have no similarity with any existing clade and they never show shrinkage or compaction (in contrast the Marwar specimens show wrinkles and folds like carbonaceous megafossils Chuaria, see Srivastava, 2012c). Retallack (1994) and Peterson et al. (2003) proposed fungal affinity. Irrespective of biologic affinity and taxonomic position of these discs, there is no doubt about their biogenicity (consistent and repetitive morphological features like smoothness and crenulations on margins, well preserved inner circular body with presence or absence of outer sheath or covering-like structures) as well the Ediacaran age of the host rock, comprising them. These fossils document an important evolutionary episode just before the “Cambrian Explosion” and reveal information about early macroscopic evolution of multicellular complex life (Xiao and Laflamme, 2008).

In terms of age the Ediacaran discs are considered to be the oldest (Hofmann et al., 1990) and possibly the youngest (Hagadorn et al., 2000) Ediacaran fossils known so far. They represent potentially the most important constituent of the biota of that particular period.

Recent studies indicate that Ediacaran fossils epitomize a phylogenetically diverse biosphere probably including animals, protists, algae, fungi and others. In general, cnidarian affinity is considered for most of these discs. Their simple ecology is dominated by epibenthic osmotrophs, deposit feeders and grazers (Glaessner, 1984; Gehling, 1991).

As mentioned earlier, Ediacaran discs in present assemblage exhibit size range between 2 and 15 cm (Fig. 4) and very few exceptionally large-sized discs (Fig. 5). However, Hagadorn et al. (2002), Hagadorn and Belt (2008) and Tarhan (2008) have reported even larger medusoid fossils from the Wisconsin and New York, USA, here diameter reaches up to 95 cm, but they are from the younger sediments of middle Cambrian age (Table 2).

Unlike general trend of sudden increase in size of organisms in Ediacaran period and further decrease in size during Cambrian, the medusoids continued increasing in size in Cambrian also, which is the most significant aspect of present assemblage. Morphology exhibited by these large-sized Jodhpur Ediacaran discs (Figs. 3 and 4), comprises a robust circular to sub-circular discs, with or without centrally located smaller disc circular in shape and interpreted as oral side of the organism (Figs. 3A and 4B,C,D,E,G,H). In present assemblage, few specimens of discs occur in association with microbial mats, which are believed to have stabilized the sediments and created “death masks” of the fossils, a process not normally seen in modern environments (Gehling, 1991; Narbonne, 1998). Ediacaran discs of the present assemblage sometimes occur with weed or macroalga-like structures, comprising holdfasts and horizontal rhizome-like structures (Fig. 5A,B), indicative of their benthic habitat (Srivastava, 2011), hence bear palaeobiological significance.

Discoidal features can reasonably be related genetically to the microbially originated gas domes or “discoidal microbial colonies”.

Figure 6. Size distribution patterns (scatter diagram) of Ediacaran discs measured in Sursagar and Artiya Kalan areas of the Jodhpur Sandstone Formation, Marwar Supergroup, western Rajasthan.

Figure 7. Size distribution patterns (bar-diagram) of Ediacaran discs measured in Sursagar and Artiya Kalan areas of the Jodhpur Sandstone Formation, Marwar Supergroup, western Rajasthan.
A number of discoidal structures have even been re-interpreted as scratch circles produced by objects rooted to soft sediment surfaces (Grazhdankin, 2000, 2003; Jensen et al., 2002; Mapstone and Mcllroy, 2006). Some of the discoidal features consisting of lobes radiating out from a central circle have been interpreted as microbial mat related decay gas domes (Seilacher et al., 2005; Seilacher, 2007). In contrast exceptionally large-sized discs discussed in present paper exhibit different morphology which is well comparable with Ediacara form Aspidella. Here author also considers the Aspidella, as a form taxon of similar looking and similar living organisms without indicating a particular phylogenetic relationship.

Presence of Ediacaran discs in Jodhpur Sandstone and their absence in younger Bilara and Nagaur groups suggest the end of a typical taphonomic window mediated by microbial activity. Their global scarcity in younger assemblages indicates a more likely scenario of extinction or at least ecological restrictions (Gehling, 1991; Narbonne, 2005). Detailed study of fossil bearing Jodhpur Sandstone and its depositional environment is needed for more precise geochronological and evolutionary palaeobiological interpretations.

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References


Shrivastava, P., 2011. Well preserved complex morphologies in siliciclastic rocks of Ediacaran age, the Marwar Supergroup, India. In: Gordon Research Conference on Geobiology, California, USA.


Shrivastava, P., 2012b. Problematic worms and Priapulid-like fossils from the Nagra group, the Marwar Supergroup, Western Rajasthan, India. Ichnos 19, 156–164.


