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REASSESSMENT OF THE MACROFLORA OF THE PARSORA FORMATION WITH REMARKS ON THE AGE CONNOTATION

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ABSTRACT

The macroflora of the Parsora Formation is unique in terms of its diversity and comprises a diverse array plant groups. Variety of plant macrofossils having affinities with pteridophytes, pteridosperms and gymnosperms have been reported and described earlier from the Parsora Formation since the last phase of 19th century. However, affinities and identification of some of the taxa reported earlier from the Parsora Formation namely, *Neocalamites foxii* Lele, *Cladophlebis* sp. cf. *C. denticulata* Lele, *Taeniopteris* ?*spatulata* McCelland, *Desmiophyllym indicum* Sahni*, Biera indica* Lele species of *Araucarites* have been questioned earlier by a number of workers. The most commonly occurring macrofossil of the Parsora Formation is *Dicroidium,* the age-diagnostic Triassic marker taxon. In the present study, a number of species of *Dicroidium* described earlier have also been thoroughly reassessed. The age of the Parsora Formation is controversial from the biostratigraphic point of view and this controversy is yet to be resolved. Earlier, based on the occurrence of *Estheriella*, an Early Triassic age had been assigned for the Parsora Formation; however, evidences of plant macrofossils and palynofossils indicate a younger age. It may be mentioned here that some plant macrofossils having Late Permian and Early Triassic affinities were reported earlier from the so called Parsora Formation. This created more controversy for the age connotation of the formation. The present contribution is focussed to revise and reassess the macroflora of this lithounit and to resolve the age of the Parsora Formation based on both biostratigraphy and lithostratigraphy. Correlation with the Triassic macroflora known from other parts of the world has also been done.

Keywords: Parsora Formation, plant macrofossils, Reassessment, age connotation

INTRODUCTION

Since 1882, a variety of plant fossils have been reported from the Parsora Formation (Feistmantel, 1882; Seward, 1932; Lele, 1953, 1955, 1962a, 1962b, 1963, 1969; Saksena, 1952; Sahni and Rao, 1956; Rao and Lele, 1963; Vimal and Singh, 1968; Shah *et al*. 1971; 1973; Sastry *et al*. 1977; Sukh-Dev, 1987; Bose *et al*. 1990; Pal*,* 1985; Pal and Sur, 2003; Tarafdar *et al*. 1993; Shah, 2000). However, record of animal fossils is scanty and there are direct (Ghosh *et al*. 2007) or indirect (Ghosh *et. al.* 2014) evidences of insects from this formation. Plant macrofossils collected from several localities of the Parsora Formation in the South Rewa Gondwana Basin are housed in the museum of Birbal Sahni Institute of Palaeosciences and those have been documented in a number of contributions (Lele, 1953; 1955; 1962a; 1962b; 1963; 1969; Rao and Lele, 1963). But, Bose (1974) opined that some of these forms are of doubtful affinities namely, *Neocalamites foxii* Lele, *Cladophlebis* sp. cf. *C. denticulata* Lele, *Taeniopteris* ?*spatulata* McCelland, *Baiera indica* Lele, *Desmiophyllum indicum* Sahni and two new species of *Araucarites*. The genus *Dicroidium,* a marker taxon of southern hemisphere Triassic flora, was first reported from the Parsora Formation of India in the South Rewa Gondwana Basin. *Dicroidium* has long been designated as an index genus of the Gondwanan Triassic that replaced the widespread Glossopterids after the end-Permian mass extinction (Retallack, 1995). However, *Dicroidium* has also been reported from the Upper Permian of Jordan where it has been recorded in association with Cathaysian elements (Kerp *et al.* 2006; Hamad *et al.* 2008). These significant findings have been discussed in the present paper. In the present study, we have critically reassessed the plant macrofossils from different localities of the Parsora Formation and interpreted the age of the formation, integrating the data of lithostratigraphy, plant macrofossils and palynozontaion.

GEOLOGICAL SETTING

The fossiliferous unit near the Parsora Village (81˚05’ E: 23˚24’ N) in Umaria Distrct, Madhya Pradesh was named as the Parsora Formation by Cotter (1917). The Parsora Formation has been variously designated from time to time, such as Mahadevas (Hughes, 1881), “Transitional Bed” (Feistmantel, 1882), Supra-Barakars (Hughes, 1884), Parsora Bed (Cotter, 1917), Parsora Group (Rao and Sukla, 1954) and Parsora Stage (Lele, 1964). Later on, the Parsora Formation was mapped by Dutta and Ghosh (1972). This unit is about 400 meters thick and comprises a basal siltstone-mudstone succession followed upward by an essentially arenaceous facies. Lithologically, it is characterized by medium to coarse-grained sandstone with pebbly horizon, interspersed with lenses of micaceous mudstone. They are also found to be associated with fine micaceous sandstones, argillaceous sandstones and mottled shales. Hard red coloured shales and ironstone bands are also common. Cross-bedding is a common feature. Occurrence of multi-coloured rocks is the characteristic feature of this formation with micaceous mudstones, mottled in shades of red, lilac and violet. The Parsora Formation extends from Somarkoini (23˚37’ N: 81˚10’ E) in the north to Chota Daigaon (23˚23’ N: 81˚02’ E) in the west and beyond Murch-Pass (23˚22’ N: 81˚12’ E) in the east. In the south, the sedimentary stratum unconformably overlies the Precambrian metamorphic rocks. This lithounit has a tendency to form low lying ridges. At Bandhavgarh Fort (23˚41’ N: 81˚01’ E), the Jabalpur Formation (early Cretaceous) overlies the low dipping Parsora Formation. The formation is

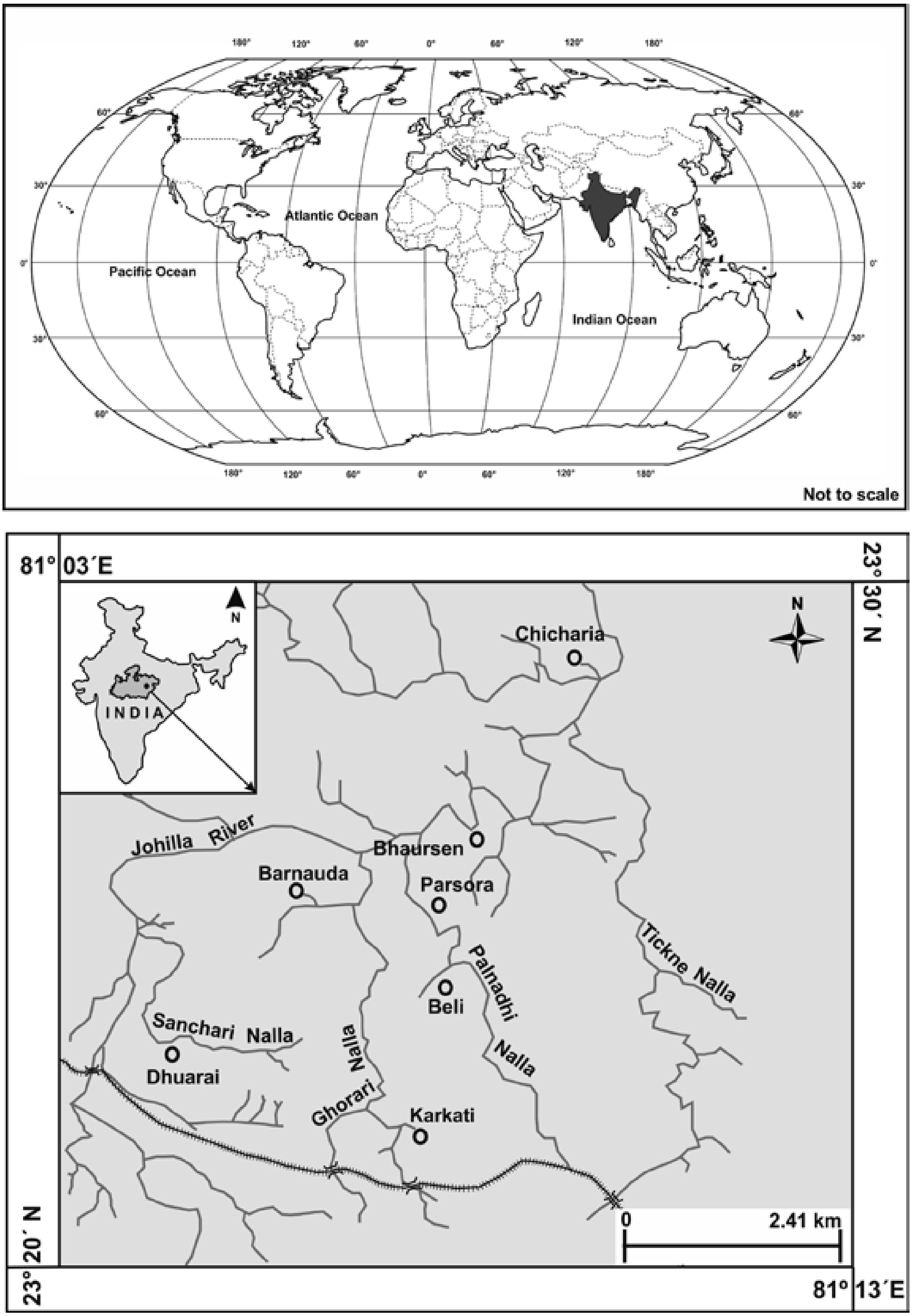

Fig. 1. World map showing India and location map showing the study area within India.

best developed and exposed in the large part of the Ghorari Nala, including Parsora Village as well as in the Palnadahi Nala locality near Beli, Dhaurai Hill near Birsinghpur-Pali and near Beohari (Fig. 1 and 2). The Parsora Formation unconformably overlies the Tiki Formation, however, the nature of the upper contact is uncertain. This lithounit constitutes the youngest horizon of the South Rewa Gondwana Basin (Fig. 3).

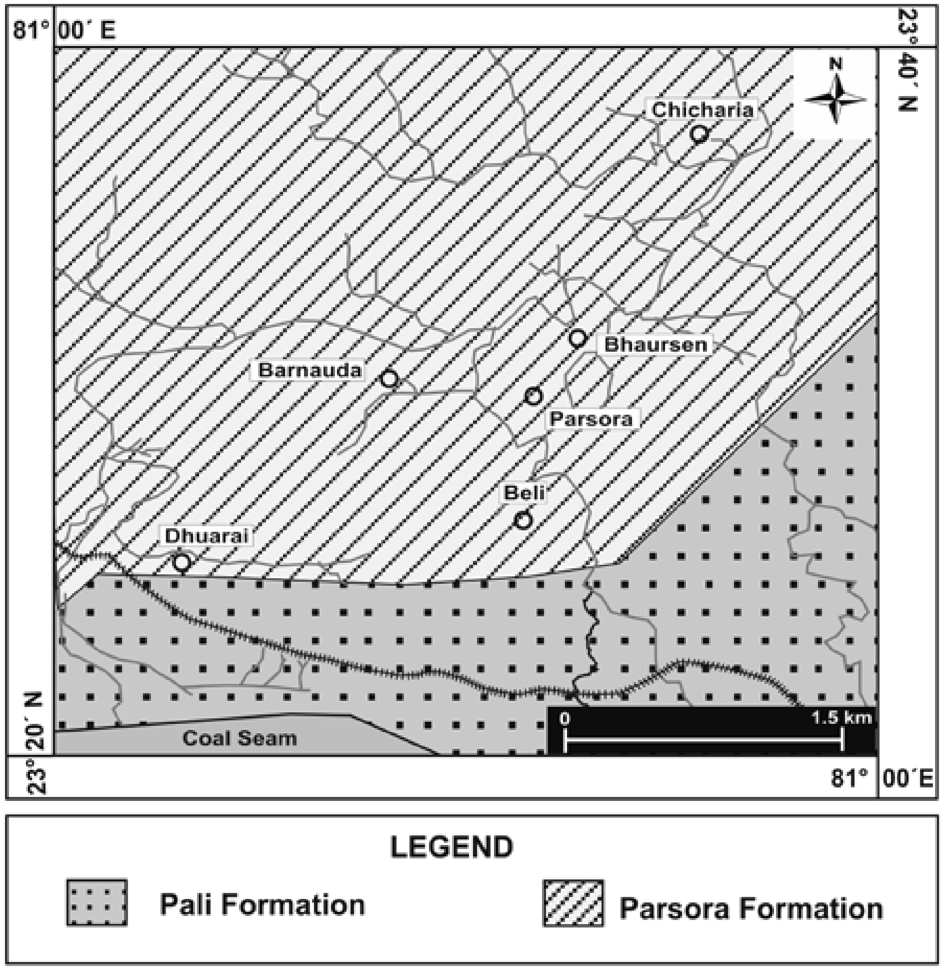

Fig. 2. Geological map of part of the Johilla Coalfield showing the fossil localities of Parsora Formation (modified after Ghosh *et al*., 2007).

MATERIALS AND METHODS

The specimens for the present study were collected by K.M. Lele of Birbal Sahni Institute of Palaeosciences from Parsora, 5 ½ miles north-east of Pali (Birsinghpur railway station on Katni-Bilaspur line), Beli, Chicharia, Barnauda and Bhaursen locality. All the specimens are housed in the repository of Birbal Sahni Institute of Palaeosciences. The specimens are preserved predominantly as impressions on red coloured mottled shales.

The hand specimens were studied and observed under unilateral incident light for the study of external surface features. Photographs of macrofossils were taken using Nikon D2X digital camera under strong reflected light at various angles to get a clear expression of surface features.

SYSTEMATIC DESCRIPTION

Subdivision **Euphyllophytina** Kenrick and Crane, 1997
Family **Equisetaceae** de Candolle, 1804
Genus ***Paracalamites*** Zalessky, 1927

Paracalamites foxii (Lele) com. nov.
(Fig. 4 A)

Neocalamites foxii Lele, 1955, p. 23-24; pl.1, figs. 2,6,7.

Description: Fragmentary specimens of shoots, largest one measuring 18.7 X 3.6 cm. Shoots articulated i.e., differentiated into nodes and internodes, nodes slightly widened and swollen, about 4 mm wide, internodes elongated, measuring 3 cm. Internodes traversed by parallel, regular, conspicuous ridges and grooves. On an average 12-14 ridges and grooves per cm are present and continue from one internode to the other. Leaf-sheaths are lacking in all the studied specimens.

Remarks: Lele (1955) assigned the above specimen under the genus *Neocalamites* based on the presence of nodes and internodes with the internodes traversed by parallel, regular ridges and grooves. However, Bose (1974) opined that in the absence of the leaf-sheaths, the specimen is more akin to equisetaceous stem. The present study also reveals that the specimen described by Lele (1955) resembles equisetaceous stem in its gross morphological features but the leaf-sheaths are absent. Zalessky (1927) erected the genus *Paracalamites* for the inclusion of equisetaceous stems without leaf-sheaths. This concept was also supported by later workers (Boureau, 1964; Rigby, 1966; Holmes, 2001 and others). In view of this, the specimen described by Lele (1955) as *Neocalamites* has been placed under the genus *Paracalamites* Zalessky and a new combination has been proposed.

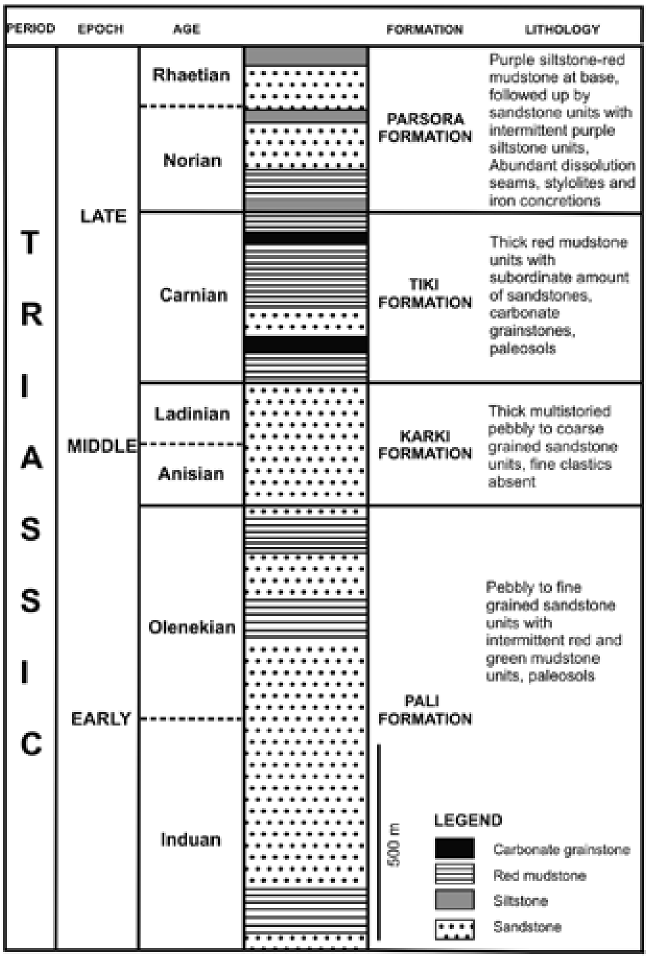

Fig. 3. Lithostratigraphic and biostratigraphic succession of the Triassic sediments in South Rewa Gondwana Basin with generalized lithlog showing the different lithologies (modified after Mukhopadhyay *et al*., 2010; Mukherjee *et al*. 2012; Chatterjee *et al*., 2014 and Ghosh *et al*., 2014).

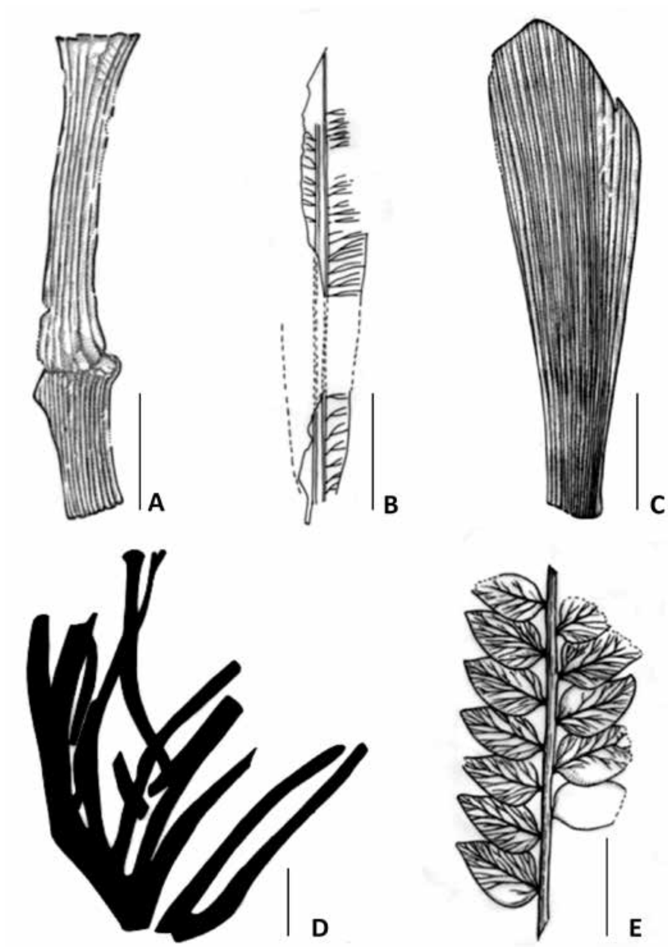

Fig. 4. A) *Paracalamites foxii,* Specimen No. BSIP 5104. B) *Taeniopteris parvilocus,* Specimen No. BSIP. 8993 C) *Desmiophyllum indicum,* Specimen No. BSIP 9003. D) *Baiera indica,* Specimen No. BSIP 8924. E) *Cladophlebis denticulata,* Specimen No. BSIP 8993. (Scale bars = 0.5 cm).

Figured specimen: BSIP Specimen No. 5104.

Locality: 5 ½ miles north-east of Pali Village, Umaria District, Madhya Pradesh.

Horizon and Age: Parsora Formation, late Triassic.

Division **Lycopodiophyta** Scott, 1900
Class **Isoetopsida** Rolle, 1885
Order **Selaginellales** Wettst, 1903
Family **Selaginellaceae** Reichb, 1837
Genus ***Selaginellites*** Zeiller, 1906

Selaginellites indicus (Lele) comb. nov.
(Pl. I, fig. f)

Araucarites indica Lele, 1962b, p. 79; pl. 4, figs. 33-36, Text-fig. 9.

Description: Detached sporophylls more or less sub-rhomboidal in outline and distal end obtusely pointed. Basal part roughly wedge shaped, measuring 9 X 6 mm, distal part forms a long, triangular spine, measuring 5 mm in length and 3 mm in width at the base. Distinct median groove present in the distal spinal region that ends in the proximal part as a single, rounded depression. A prominent keel resembling ligule is found to be attached near the circular depression on the lower surface.

Remarks: The absence of any adnate seed supports the separation of the taxon from *Araucarites* (Gee and Tidwell, 2010). In all probabilities, the rounded depression may be the region of megasporangium as evidenced by the presence of ligule and isolated megaspores found as impressions in the same matrix. Based on the foregoing account, the specimen described by Lele (1962b) as a new species of *Araucarites* i.e., *Araucarites indica* has been placed under the genus *Sellaginellits* Zeiller and a new combination has been proposed.

Figured specimen: BSIP Specimen No. 9016.

Locality: Beli, Umaria District, Madhya Pradesh.

Horizon and Age: Parsora Formation, late Triassic.

Class **Lycopodiopsida** Bartling, 1830

EXPLANATION OF PLATE I

a) ***Taeniopteris parvilocus****,* Specimen No. BSIP 8781. b) ***Cladophlebis denticulata****,* Specimen No. BSIP 8993. c) ***Baiera indica****,* Specimen No. BSIP 8924. d) ***Desmiophyllum indicum****,* Specimen No. BSIP 9003. e) ***Samaropsis parsorensis****,* Specimen No. BSIP 8711. f) ***Selaginellites indicus****,* Specimen No. BSIP 9016. g) ***Lycopodites*** sp., Specimen No. BSIP 9008. h) ***Dicroidium zuberi****,* Specimen No. BSIP K25/567.

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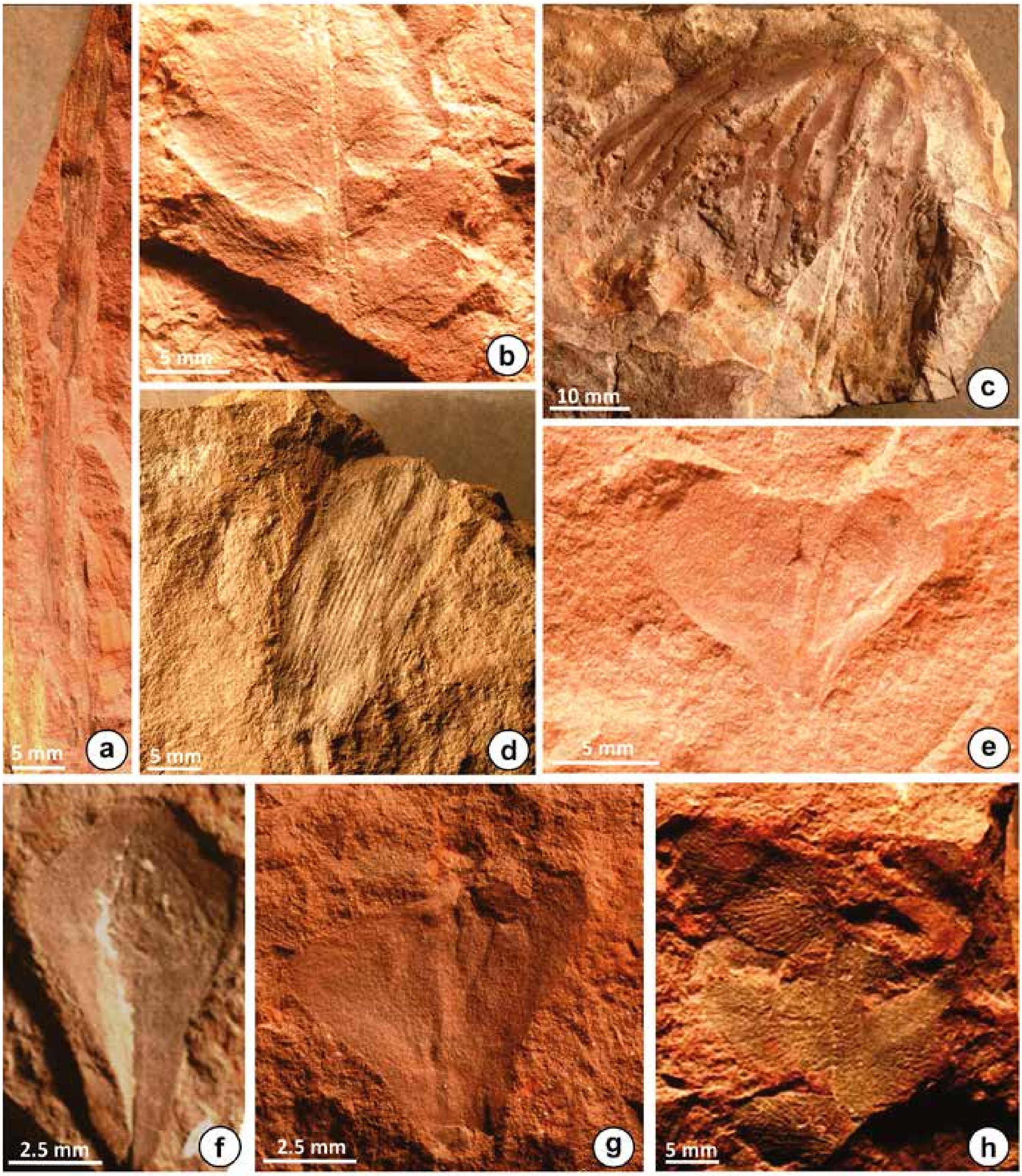
Plate I



Order **Lycopodiales** de Candelle ex Berchtold and Presl, 1820
Family **Lycopodiaceae** Beauvois ex Mirbel, 1820
Genus ***Lycopodites*** Lindley and Hutton, 1833

Lycopodites sp.
(Pl. I, fig. g)

Araucarites sp. Lele, 1962b, p. 79-80; pl. 4, figs. 38-41, text-fig. 10.

Description: A thin, delicate, scale leaf, more or less triangular in outline, measuring 5 mm at the broadest distal region and 4 mm in length. Tip is not well preserved. Towards the proximal region, the scale tapers and forms a narrow and truncated base. A distinct median ridge runs throughout the entire length. Remains of seed or associated scar are indiscernible.

Remarks: The scale leaves are devoid of any scar or its traces. The overall characteristic features of the specimens resemble the scale leaf of *Lycopodites*. However, in the absence of detailed morphological features, the specimens described earlier by Lele (1962b) as *Araucarites* sp. have been assigned under the genus *Lycopodites* Lindley and Hutton (1833).

Figured specimen: BSIP Specimen No. 9008.
Locality: Beli, Umaria District, Madhya Pradesh.
Horizon and Age: Parsora Formation, Late Triassic.

Order **Filicales** Scott, 1909
Family **Osmundaceae** Benchtold and Presl, 1820
Genus ***Cladophlebis*** Brongniart, 1849

Cladophlebis denticulata (Brongniart) Fontaine emend. Harris, 1961
(Pl. I, fig. b; Fig. 4 E)

Cladophlebis sp. cf. *C. denticulata* Lele, 1962b, p. 72-73; pl.1, figs.11,12; pl. 2, figs.13,14.

Description: Incompletely preserved specimen of pinna measures 3 cm in length and 1.3 cm in width at the broadest region. It possesses a slender rachis measuring approximately 1 mm in thickness. Pinnules closely spaced, alternately inserted at an angle of 45-50˚. Pinnules are small, ovate to triangular in shape with an entire to slightly undulating margin. Pinnules possess an acute apex and measure 5-7 mm in length and 3-4 mm in breadth with a persistent midrib measuring 0.3 mm in thickness that gradually evanesces towards the apex. The secondary veins emerge at an angle of 40-45˚, fork once or more before reaching the margin.

Remarks: The genus *Cladophlebis* has been considered as the sterile *Osmunda*-like foliage (Brongniart, 1849). It has been extensively reported from the Triassic of Gondwana countries (Orlando, 1968; Retallack, 1983; Morel *et al*. 1999; Nielsen, 2005; Kustatscher *et al*. 2012). Lele (1962b) compared the specimens of *Cladophlebis* from Parsora Formation with *Cladophlebis denticulata* (Brongniart) Fontaine described by Harris (1961) from the Jurassic of Yorkshire. However, Bose (1974) commented that the specimens of Parsora Formation described by Lele (1962b) are quite different from the Yorkshire specimens because in the Parsora specimens the secondary veins fork more than once before reaching the margin, while in the Yorkshire specimens, excepting the basal pair of veins, the rest divides only once before reaching the margin. However, the present study reveals that in gross morphological features and venation pattern, the Parsosra specimens described by Lele (1962b) as *Cladophlebis* sp. cf. *C. denticulata* resemble *Cladophlebis denticulata* (Brongniart) Fontaine. The margin of the Parsora specimen is entire to undulating, which is also comparable to *Cladophlebis antarctica* Halle. It should be mentioned here that Halle (1913), when established *Cladophlebis antarctica,* noticed its close similarity with *C. denticulata*. Both the species were later described and illustrated separately by Gee (1989), Rees and Cleal (2004) and Birkenmejer and Ociepa (2008). However, Rees and Cleal (2004) opined that *Cladophlebis denticulata* (Brongniart) Fontaine and *Cladophlebis antarctica* Halle might be conspecific and suggested merger of the two species i.e., *C. denticulata* and *C. antarctica* with emended diagnosis. While describing Liassic ferns from Hungary, Baraback and Bordor (2008) opined that the difference of taxonomic features between the two species are the number (or density) of secondary veins and their bifurcations and this may be due to the morphological differentiation of the same species resulted from environmental factors. Based on the foregoing account, the specimen described here can be safely assigned to *Cladophlebis denticulata* (Brongniart) Fontaine.

Figured specimen: BSIP Specimen No. 8993
Locality: Beli, Umaria District, Madhya Pradesh.
Horizon and Age: Parsora Formation, Late Triassic.

Division **Spermatophyta** Eichler, 1883
Class **Gymnospermopsida** Stewart and Rothwell, 1993
Order **Corystospermales** Petriella, 1981
Family **Corystospermaceae** Thomos, 1933
Genus ***Dicroidium*** Gothan, 1912

Dicroidium hughesii (Feistmantel) Lele, 1962a
(Pl. II, fig. b, d; Figs. 5 C, F-G)

Thinnfeldia (*Danaeopsis*) *hughesi* (Feistmantel) Seward, Lele, 1955, p.24-25; pl. 2, figs. 8, 12, 14, 15, 24; text-fig. 1.
Dicroidium hughesi (Feistmantel) Gothan, Lele, 1962a; p. 56-59; pl. 3, figs. 14-22, text-figs. 6A-Q.
c.f. *Dicroidium hughesi* (Feistmantel) Gothan, Lele, 1962a, p. 59-61; pl. 4, figs. 23-33; text-figs. 4A, B.
Dicroidium odontopteroides (Morris) Gothan, Lele, 1962a, p. 51-54 (part), pl. 1, fig. 3; text-figs. 2C-E.

Description: Frond once-pinnate, imparipinnate, up to 50 cm long. Rachis proximately forked once. Pinnules opposite to sub-opposite, typically oblong-lanceolate, gradually become shorter towards the leaf base. At the base, the rachis forks and pinnules become almost orbicular in shape. Each pinnule attached by whole broad base with basiscopic margin decurrent along the rachis; lateral margin of pinnules entire; apex obtuse to sub-acute. Typically each pinnule with a distinct midvein, besides midvein a few veins arise at an angle of about 40˚, slightly arching, mostly once forked.

Remarks: Based on a collection from the Parsora Formation, Lele (1955) described this species as *Thinnfeldia (Danaeopsis) hughesii* (Feistmantel) Seward. Later on, Lele (1962a) described it under the genus *Dicroidium*, as *D. hughesii*. The specimens are preserved as impressions in fine-grained ferruginous sandstones and devoid of any phytoleimma. In some specimens, ferruginous crusts have been observed at places that show the epidermal features to certain extent under strong reflected light. However, Lele (1962a) could not find a stoma in the upper surface away from the midrib region and therefore opined that stomata on the upper surface are very rare and probably occur on or close to the midvein. Moreover, owing to poor preservation, it is difficult to recognize a stoma properly. Several specimens of *D. hughesii* from the Parsora Formation depict the proximal forking of the rachis. Specimens of *Dicroidium odontopteroides* described by Lele (1962a) are likely to be smaller forms of *D. hughesii*. *Dicroidium hughesii* is of common occurrence in the Parsora Formation (Norian-Rhaetian).

Figured specimens: BSIP Specimen No. K25/567; 9084; 9090; K25/722; K25/725.

Locality: Parsora, Barnauda; Bhaursen; Chicharia, Umaria District, Madhya Pradesh.

Horizon and Age: Parsora Formation, Late Triassic.

Dicroidium zuberi (Szajnocha) Archangelsky, 1968
(Pl. I, fig. h; Pl. II, figs. a, c; Figs. 4 A-B, D-E)

Dicroidium odontopteroides (Morris) Gothan, Lele, 1962a, p. 51 (part); pl. 1; figs. 1, 2, 4-7; text-figs. 2A, B; 3A-C; 4A-C.

Dicroidium sp. cf. *D. feistmantelii* (Johnston) Gothan: Lele, 1962a, p. 54-56; pl. 8-13; text-figs.5A,F.

Dicroidium sahni (Seward) Rao and Lele, 1963, p. 9; pl. 1, figs. 1-5; text-figs. 1-4.

Parsorophyllum indicum Lele, 1969, p.314-317, pl. 1, fig. 1, pl. 2, figs. 2-4, text-figs.1-3.

Description: Pinnae upto 21 cm long, bipinnate, rachis proximately forked once. Pinnules are opposite to sub-opposite, imparipinnate. Largest available pinnule measures 8 cm in length and 3 cm in width. Pinna rachis ranges from 2-5 cm in length and possesses a distinct ridge. Pinnules are closely spaced, often touching and sometimes overlapping each other, rhomboidal to broadly oval in shape; 3-4 mm X 16-18 mm in size, apex obtuse, entire to slightly lobed margin, usually contracted at the base. Terminal pinnule oval to oblong, 3 or 4 veins arise close to the basiscopic side of pinnule base, each vein forks 1-3 times and arches towards the margin.

Remarks: From the Parsora Formation, Lele (1962a) earlier described some specimens as *Dicroidium odontopteroides* (Lele 1962a, pl. 1, figs 1, 2, 4-7; text-figs 2 A, B; 3 A-C; 4 A-C). Those specimens are assignable to *D. zuberi* on the basis of lamina segments and venation pattern. *Dicroidium* sp. cf. *D. feistmantelii* described by Lele (1962a) and *D. sahni* described by Rao and Lele (1963) from the Parsora Fromation have also been included by Pal *et al.* (2014) in *D. zuberi.* It may be mentioned here that both *D. sahnii* and *D. feistmantelii* have already been considered as *D. zuberi* by Retallack (1977)

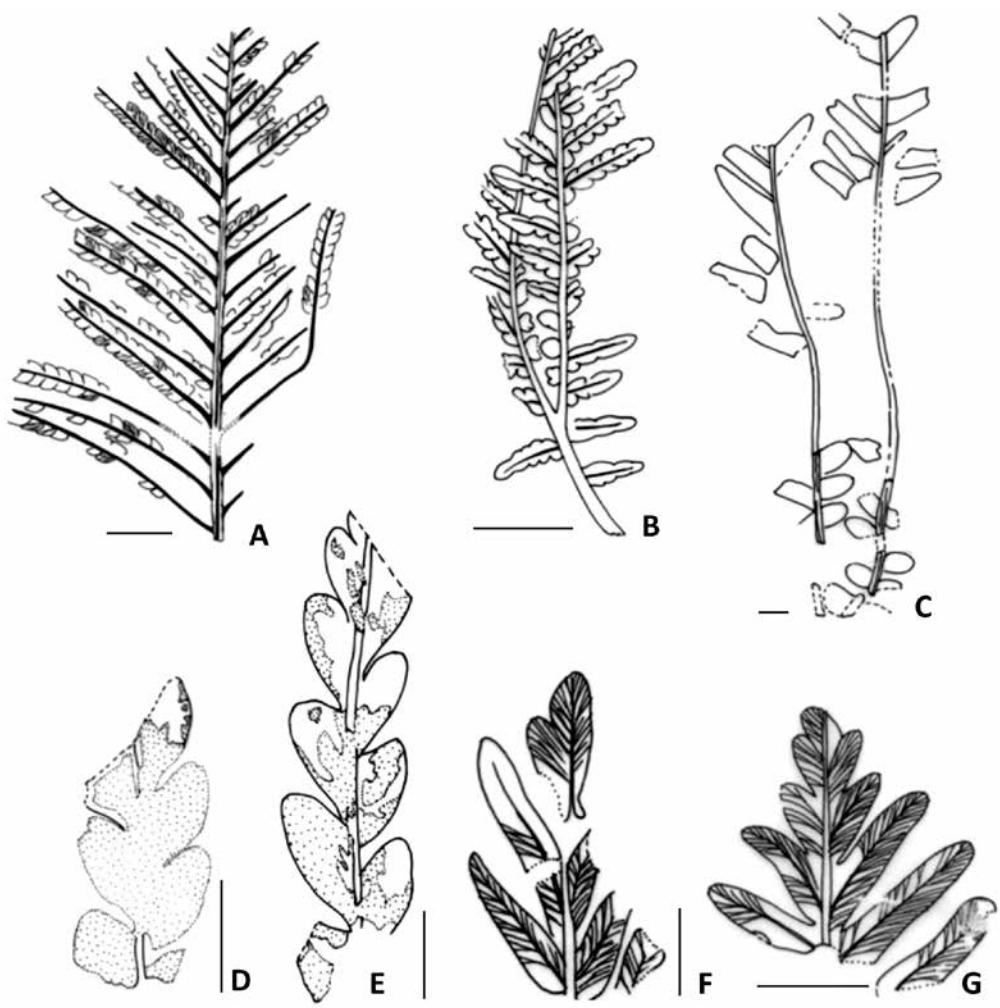


Fig. 5. A) *Dicroidium zuberi,* Specimen No. BSIP 5098. B) *Dicroidium zuberi,* Specimen No. BSIP 9103. C) *Dicroidium hughesii,* Specimen No. BSIP K25/567. D) *Dicroidium zuberi,* Specimen No. BSIP 8753. E) *Dicroidium zuberi,* Specimen No. BSIP 8753. F) *Dicroidium hughesii,* Specimen No. BSIP K25/567. G) *Dicroidium hughesii,* Specimen No. BSIP K25/567. (Scale bars = 0.5 cm).

and Anderson and Anderson (1983). Lele (1969) instituted a new genus *Parsorophyllum* from the Parsora Formation and created a new species *Parsorophyllum indicum.* The specimens of *Parsorophyllum indicum* were described earlier by Lele (1955) as *Thinnfeldia odontopteroides*. These specimens are assignable to *D. zuberi* owing to their deltoid nature of pinnules with typical venation pattern characteristic of *D. zuberi* i.e., 3 to 4 dichotomously branched primary veins concentrating at a basicopic point.

D. zuberi is consistently represented in the Triassic succession of Peninsular India. However, it is more abundant in the Tiki (Carnian) and Parsora (Norian-Rhaetian) formations of South Rewa Gondwana Basin.

Figured specimens: BSIP Specimen No. K25/563; 8753; 9103, 5098.

Locality: Parsora; Barnauda; Bhaursen; Chicharia, Umaria District, Madhya Pradesh.

Horizon and Age: Parsora Formation, Late Triassic.

Division **Gingkophyta** Taylor, 1981
Order **Gingkoales** Engler, 1897
Family **Ginkgoaceae** sporne, 1965
Genus ***Baiera*** Braun, 1843

Baiera indica Lele, 1962b
(Pl. I, fig. C; Fig. 4 D)

Baiera indica Lele, 1962b; p. 77-78; pl. 3, figs. 27-28.

Description: Incomplete frond is presumably wedge-shaped, measuring 5 cm in length and 4 cm in width at its broadest region. Petiole is lacking, frond deeply dissected and incised into number of linear, thin segments, each segment measuring 3.5-4.0 cm X 1.5-3.0 mm. Repeated dichotomy of the frond not exhibited, segments usually fork once at an angle of 40-45˚. Venation poorly preserved, not clearly discernible, however, apparently 4-5 thin veins run parallel but branching not visible.

Remarks: The genus *Baiera* is characterised by wedge-shaped leaf having a slender stalk and venation pattern similar to Gingkoales. *Baiera* have been recorded from the Carnian (Tiki Formation) of India (Pal, 1984) as well as from the middle Jurassic rocks of various localities worldwide (Seward, 2011). Evidence supports the world-wide distribution of Ginkgoales, especially *Baiera* in the older Mesozoic floras. The species of *B. indica* has characteristic segmentation unlike any other species known so far. Therefore, the institution of a new species by Lele (1962b) is justified.

Figured specimen: BSIP Specimen No. 8924.

Locality: Beli, Umaria District, Madhya Pradesh.

Horizon and Age: Parsora Formation, late Triassic.

Family **Incetae sedis**
Genus ***Taeniopteris*** Brongniart emend. Cleal and Rees, 2003

Taeniopteris parvilocus Anderson and Anderson, 1989
(Pl. I, fig. a; Fig. 4 B)

Taeniopteris ?spatulata McCl., Lele, 1955; p. 29-30; pl. 2, figs. 16, 23, 28; Text-fig. 3.

*Description***:** Fragmentary specimen measuring 9.5 cm in length and 1.2 cm in width at the broadest region. Shape of the leaf presumably narrow-elliptic, apex tends to be acute and base cuneate. Only the middle and basal parts well preserved. Margin is entire, not clearly visible at places; midvein distinct, stout and rigid, measuring 2 mm in thickness at the broadest region. Lateral veins spaced about 12-15 per 10 mm and extend about 10 to 15˚ above horizontal, curving sharply upwards at the margin of lamina. The lateral veins are once forked and rarely anastomose.

Remarks: The typification and affinity of the genus *Taeniopteris* is yet a matter of controversy (Pott and Launis, 2015). Following Miller (1889), Cleal and Rees (2003) considered *Taeniopteris vittata* as the lectotype of the genus, known from the Middle Jurassic of Stonesfield, Oxfordshire, U.K., that does not possess any cuticular features. As a matter of fact, it is not clear whether *Taeniopteris* is a cycad, bennettitalean or a member of *Nilssoniales.* Doweld (2013) proposed to conserve the generic name *Taeniopteris* with *Taeniopteris vittata* as a type. However, Pott and Launis (2015) opined that Doweld (2013) most probably overlooked the remarks of Miller (1889) and Cleal and Rees (2003) on the typification of *Taeniopteris*, though the affinity of the genus cannot be clarified based on the type species. Pott and Launis (2015) concluded that it is better to keep *Taeniopteris* as an illegitimate genus and proposed not to conserve it at all. But, at the same time the authors commented that various species of the genus have been validly published and according to Article 55 of International Code of Nomenclature for algae, fungi and plants (Melbourne Code, McNeill *et al*. 2012) it can be conserved as legitimate for the fossil leaves having characteristic shape and venation pattern without any cuticle. The features of the presently studied specimens resemble the generic diagnosis of *Taenopteris* Brongniart. Bose (1974) opined that the figured specimens of Lele (1955, Plate 2, figs. 16, 23) from the Parsora Formation belong to *Pterophyllum sahnii* based on the nature of secondary veins, which after emergence at places form cross-connections close to the midrib. However, shape, size, nature of midvein and lateral veins of the Parsora specimen reassessed in the present paper and earlier described by Lele (1955) indicate their close affinity to the genus *Taenopteris*. A comparative study of the different species of *Taenopteris* reveals that in gross morphological features viz., size, shape, venation pattern etc. the above described specimen resembles *Taenopteris parvilocus* Anderson and Anderson (1989) known from the upper Triassic of Molteno Formation (South Africa) and Middle Triassic of Esk Formation (McLoughlin, 2011), Queensland (Australia). It may be mentioned here that from the Triassic strata of India, *Taeniopteris* is known only from the Late Triassic of Parsora Formation. However, it has been extensively reported from the Triassic of other Gondwana countries viz., Australia, New Zealand, South Africa, Antarctica and Argentina (Table 1).

Figured specimen: BSIP Specimen No. 8781.

Locality: 5 ½ miles north-east of Pali village, Umaria District, Madhya Pradesh.

EXPLANATION OF PLATE II

a) ***Dicroidium zuberi,*** Specimen No. BSIP 5098. b) ***Dicroidium hughesii,*** Specimen No. BSIP K25/567. c) ***Dicroidium zuberi,*** Specimen No. BSIP 8753. d) ***Dicroidium hughesii,*** Specimen No. BSIP K25/567.

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Plate II

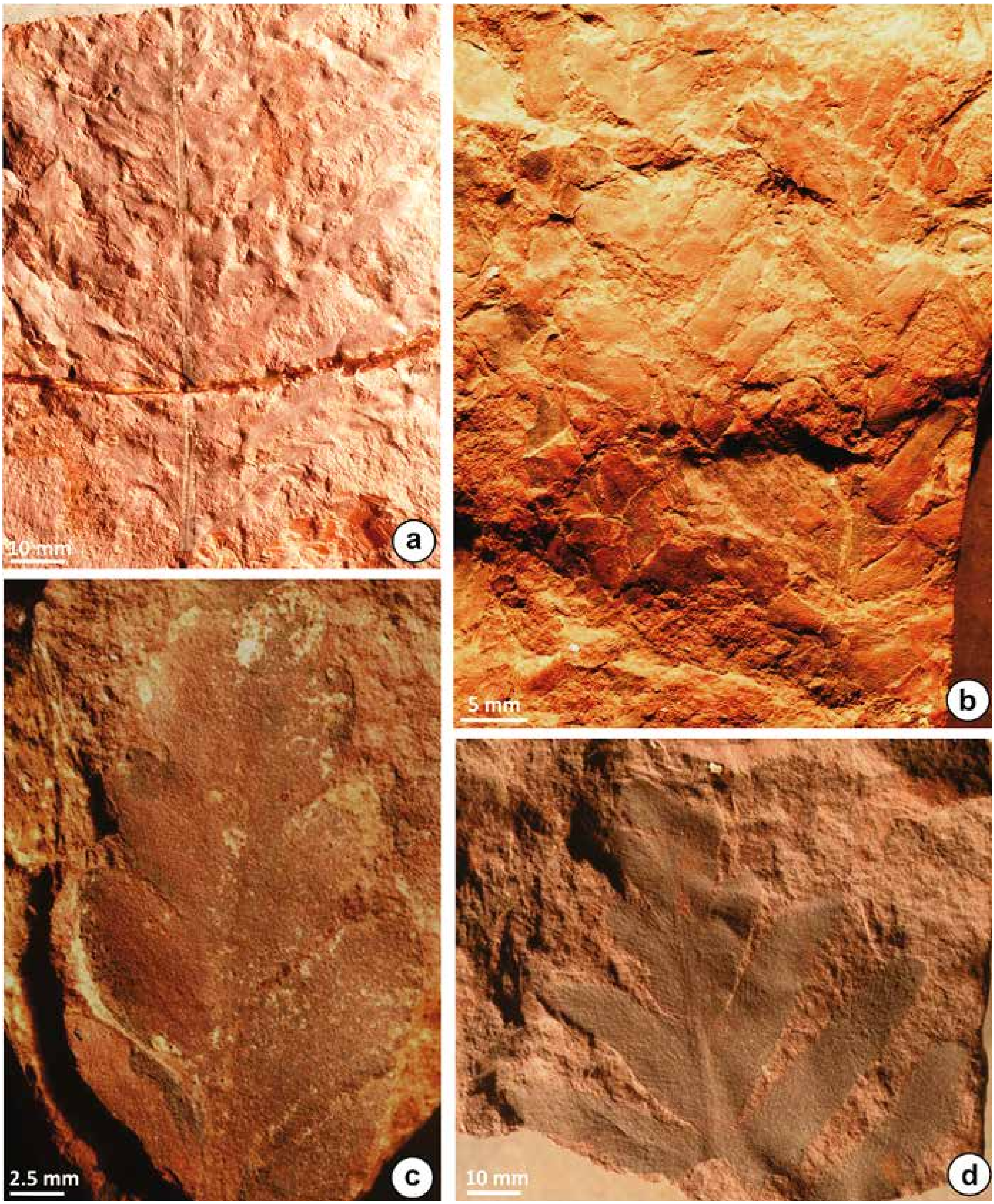

Table 1: Occurrence of *Cladophlebis, Taeniopteris* and *Baiera* in the Triassic of other countries.

GENERA	AGE	COUNTRY	AUTHOR
Cladophlebis	Middle Triassic Latest Triassic Triassic	New Zealand Argentina South Chile	Retallack, 1983 Morel *et al.* 1999 Nielsen, 2005
Taeniopteris	Triassic Triassic Triassic Middle Triassic Middle Triassic Upper Triassic	Argentina Australia Antarctica New Zealand Australia South Africa	Artabe *et al.* 2007 Holmes and Anderson, 2013 Axsmith *et al.* 2007 Retallack, 1983 McLoughlin, 2011 Anderson and Anderson, 1989
Baiera	Upper Triassic Upper Triassic	Chile New Mexico	Moisan *et al.*, 2010 Ash, 1989

Horizon and Age: Parsora Formation, late Triassic.

Genus ***Desmiophyllum*** Lesquereux emend. Solms-Laubach, 1904

Desmiophyllum indicum Sahni, 1928
(Pl. I, fig. d; Fig. 4 C)

Desmiophyllum indicum Sahni, Lele, 1962b, p. 80; pl. 4, figs. 42-44.

Description: Both part and counterpart of an incomplete leaf preserved, measuring 7 cm in length and 2.5 cm in width. Leaf strap shaped, apex obtuse, gradually becomes narrow towards base. Venation more or less parallel and evenly spaced, less than 0.5 mm apart. Veins are fewer in number near the base and increases towards the apex.

Remarks: The affinity and systematic position of *Desmiophyllum* are doubtful. Retallack (1981) suggested the non-committal name of *Desmiophyllum* for the strap-shaped fossil leaves with parallel venation and considered them as incertae sedis. The specimen of *Desmiophyllum indicum* described by Lele (1962b) from Beli, was questioned by Bose (1974) and he commented on its affinity with a ginkgoalean leaf or a species of *Noeggerathiopsis*. The present study of the specimens clearly indicate that in having parallel venation of the strap-shaped leaf, it is undoubtedly a species of *Desmiophyllum* and resembles *Desmiophyllum indicum* of Sahni (1928).

Figured specimen: BSIP Specimen No. 9003.

Locality: Beli, Umaria District, Madhya Pradesh.

Horizon and Age: Parsora Formation, late Triassic.

Genus ***Samaropsis*** Göppert, 1864

Samaropsis parsorensis (Lele) comb. nov.
(Pl. I, fig. e)

Araucarites parsorensis Lele; 1955, p. 30-31; pl. 2, figs. 13.

Description: An impression specimen measuring 1.1 to 1.3 cm in length and 1.2 to1.4 cm in width, more or less triangular to pear-shaped, platyspermic, orthotropous and surrounded by a wing (sarcotesta). Surface exhibits fine, longitudinal, divergent venation. Sarcotesta is broadly triangular in outline, fleshy, thick and broadest at the distal end measuring about 2.5 mm in width, however, gradually becomes narrow towards the proximal end and is about 1.2 mm in width.

Remarks: The specimen described by Lele (1955) was considered as the ovuliferous scale of *Araucarites* and he instituted a new species, i.e. *Araucarites parsorensis*. Bose (1974) pointed out that the specimen figured by Lele (1955) was upside down and suggested its affinity with *Samaropsis*. Our study also reveals that the specimens described as *Araucarites parsorensis* are assignable to *Samaropsis* and in view of this a new combination has been proposed. The winged seeds referable to *Samaropsis* are common in the Palaeozoic. Ash (2011) also included the Mesozoic seeds under the genus *Samaropsis.*

Figured specimen: BSIP Specimen No. 8711.

Locality: 5 ½ miles north-east of Pali village, Umaria District, Madhya Pradesh.

Horizon and Age: Parsora Formation, late Triassic.

DISCUSSION

In the present study reassessment of the plant macrofossils from the different localities of Parsora Formation has been accomplished which have been debated by a number of workers owing to their doubtful affinities. Lele (1955) designated some specimens as *Neocalamites foxii* from the Parsora Formation exposed about 8 km NE of Pali Village and his assignment was based on specimens possessing nodes and internodes without any leaf sheath. These are the characteristic features of *Paracalamites*. Hence, the specimen described earlier as *Neocalamites* has been included under *Paracalamites* and a new combination has been proposed. Lele (1962b) described sterile *Osmunda*–like foliages as *Cladophlebis* sp. cf. *Cladophlebis denticulata* from the Parsora Formation exposed in Beli (Umaria District). Critical reassessment of the specimens reveals that the *Osmunda*-like foliages belong to *Cladophlebis denticulata*. An incomplete leaf of *Taeniopteris spatulata* described by Lele (1955) from a locality about 8 km NE of Pali Village was considered as the basal part of *Pterophyllum sahnii* by Bose (1974). However, present study of the specimens affirms the retention of the generic name *Taeniopteris*. Besides, a comparative study of the different species of *Taenopteris* reveals that in gross morphological features the specimens resemble *Taenopteris parvilocus* Anderson and Anderson (1989) known from the Upper Triassic of Molteno Formation (South Africa) and Middle Triassic of Esk Formation (McLoughlin, 2011), Queensland (Australia). *Desmiophyllum indicum* was described and illustrated by Lele (1962b) from the Parsora Formation of Beli. On the basis of nature of veins, Bose (1974) suggested its affinity with a ginkgoalean leaf or a leaf of *Noeggerathiopsis*. However, our study confirms its close affinity with *Desmiophyllum indicum*. Bose (1974) opined that *Baiera indica* described by Lele (1962b) from Beli is not comparable to any *Baiera* known from the Jurassic-early Cretaceous of elsewhere as its segmentation of fronds is very peculiar; hence, its affinity is doubtful. However, our observation reveals that the wedge-shaped leaf with slender stalk and venation pattern resembles the characteristics of *Baiera* and has been extensively recorded from the late Triassic to Middle Jurassic (Pal, 1984; Seward, 2011). Lele (1962b) instituted the new species *B. indica* owing to its unique segmentation pattern and hence the institution of new species by Lele (1962b) is justified. Bose (1974) commented that *Araucarites indica* and *?Araucarites* sp. described and figured by Lele (1962b) from the Parsora Formation of Beli (Umaria District) are probably detached leaves of Lycopodiaceae or Selaginellaceae. We have critically re-examined the specimens and arrived at the interpretation that these are, in fact, the detached sporophylls of *Selaginella* as these possess a prominent keel resembling ligule attached near the central depression that may be megasporangium. Impressions of isolated megaspores are also preserved in the same matrix. In view of this it has been placed under the genus *Selaginellites* and a new combination has been proposed. *?Araucarites* sp. described by Lele (1962b) are basically the delicate scale leaves of Lycopodiaceae and hence it has been treated here as *Lycopodites* sp. *Araucarites parsorensis* illustrated by Lele (1955) from the Parsora Formation (8 km NE of Pali Village) was considered by Bose (1974) as *Samaropsis* and it has also been reconfirmed by our study. Apart from that a number of species of *Dicroidium, Thinnfeldia* and *Parsorophyllum* were also described and illustrated by Lele (1955, 1962a, 1969) and Rao and Lele (1963) from Parsora, Barnauda, Bhaursen and Chicharia localities of Parsora Formation. Our present reassessment and recent revision of Triassic *Dicroidium* from India (Pal *et al*., 2014) reveal that the macroflora of Parsora Formation is dominated by two species of *Dicroidium*, i.e. *D. hughesii* and *D. zuberi*. Some of the genera viz., *Cladophlebis, Taeniopteris* and *Baiera* are unique to the Indian Triassic macroflora. However, these have been reported from the Triassic sediments of other countries like Argentina, Australia, Chile, New Mexico, New Zealand and South Africa (Table 1). Species of *Cladophlebis*, *Taeniopteris* and *Baiera* have so far been reported from the Jurassic to early Cretaceous sediments of India (Surange, 1966; Bose and Shah, 1968; Roy, 1968). The macroflora of Parsora Formation bears a striking resemblance to that of Burgerdorps Formation (Triassic) near Aliwal North, South Africa (Bose, 1974; Retallack, 1996) in having *Ginkgo*-like leaves and their associated remains. It suggests that most probably some of these members successfully continued with their full vigour from the Triassic up to the early Cretaceous. From the Parsora Formation, occurrence of *Estheriella* the marker Triassic crustacean fossils (Ghosh and Shah, 1977) have been reported along with the fossilized larva of an aquatic beetle *Protodytiscus johillaensis* (Ghosh *et al.,* 2007).

It should be mentioned here that previous contributions on plant fossils from some localities assigned to the Parsora Formation are in fact having early Triassic affinity. Shah (2000, 2004) reported the co-existence of *Glossopteris* and *Dicroidium* in the same bed of the Karkati Village section in Johilla Coalfield and included it under the Parsora Formation. He suggested an age younger than early Triassic for the Karkarti section. However, the macrofloral assemblage indicates an early Triassic age equivalent to the Panchet Formation (Induan-Olenekian) of the Damodar Valley Basin and Pali Formation of the South Rewa Gondwana Basin. Based on palynological investigations, the Pali Formation has been dated as late Permian to early Triassic (Tiwari and Ram-Awatar, 1986). The macrofloral assemblage as well as lithostratigraphy also supports this view. It may be inferred that in some outcrops designated as Parsora Formation from where the typical late Permian and early Triassic plant macrofossils (dominated by glossopterids and allied taxa of late Permian affinities viz., *Sphenopteris polymorpha*, *Schizoneura gondwanensis, Phyllotheca striata, P. sahnii,* Equisetaceous stem, *Macrotaeniopteris danaeoides, Dictyopteridium sporiferum, D. sporiferum, Noeggerathiopsis hislopi, Vertebraria indica, Glossopteris communis, G. browniana*, *G. angustifolia*) have been recorded (Feistmantel, 1882; Saksena, 1950, 1952, 1962; Vimal and Singh, 1968) may belong to the Pali Formation.

On the other hand, the *Dicroidium* dominated macrofloral assemblage, devoid of any late Permian or early Triassic forms definitely belongs to Parsora Formation (Pal *et al*., 2014; Ghosh *et al*., 2014). Corystospermaceous fronds belonging to the genus *Dicroidium* are the most common elements in the Triassic strata throughout the southern hemisphere and the genus has not yet been known beyond the limits of the Triassic. The *Dicroidium* flora was very much diversified and prolific during the Triassic across the Gondwanan countries (Chatterjee *et al.*, 2013). The Gondwana was intact during the late Triassic and that facilitated the dominance of corystosperms in wide geographical area (Chatterjee and Scotese, 1999, McLoughlin, 2001). In having wide geographical distribution but a restricted geologic range, *Dicroidium* is regarded as an index genus for stratigraphic correlations and as a matter of fact, for a long time *Dicroidium* has been considered an index genus of Triassic Gondwana that replaced the widespread *Glossopteris* flora after the end-Permian mass extinction event (Retallack, 1995). But, Kerp *et al.* (2006) and Hamad *et al.* (2008) have reported *Dicroidium* in association with Cathaysian elements from the Upper Permian of Jordan. Chatterjee *et al.* (2013) opined that possibly the corystosperms may have originated in the equatorial region during the late Permian and subsequently during the Triassic they became widespread in the southern hemisphere.

The Parsora Formation also has been dated palynologically. Vijaya *et al*. (2012) identified four palynoassemblage zones for early to Late Triassic based on subsurface palynological analysis following palynozonation schemes of Tiwari and Tripathi (1992) and Tripathi *et al*. (2005). The oldest early Triassic palynozone has been correlated with *Krempipollenites indicus* zone having dominance of *Striatopodocarpites* and *Satsangisaccites*. In ascending order, this is followed by *Rimaesporites potoniei* palynozone having abundance of *Striatopodocarpites* and *Arcuatipollenites* (*Lunatisporites*). Vijaya *et al*. (2012) proposed the third palynoassemblage of Late Triassic affinity as *Tikisporites balmei* palynozone and included it in the Parsora Formation. The youngest palynozone of the Parsora Formation is demarcated by *Arcuatipollenites* (*Lunatisporites*) *tethysensis* palynozone. Vijaya *et al*. (2012) assigned a Norian age for the *Tikisporites balmei* palynozone and Rhaetian age for the *Arcuatipollenites* (*Lunatisporites*) *tethysensis* palynozone. They opined that the Parsora Formation is characterised by the first occurrence of *Callialasporites turbatus* and *Classopollis* spp. and their first occurrence is indicative of late Triassic ranging from Norian to Rhaetian age (Helby *et al*., 1987; Tripathi, 2000).

CONCLUDING REMARKS AND AGE CONNOTATION

There has been a great controversy on the age of the Parsora Formation based on lithostratigraphy (Dutta, 2002, 2004) and biostratigraphy (Shah, 2000, 2004). From the various outcrops of the Parsora Formation (Parsora, Beli, Goira, Chicheria and Dhaurai Hill), plant macrofossils have been reported by several workers (Feistmantel, 1882; Lele, 1953, 1955, 1962a, 1962b, 1963, 1969; Rao and Lele, 1963; Maheshwari and Banerji, 1978; Pal, 1985). On the basis of lithostratigraphy, Dutta (2002, 2004) suggested an early Jurassic age for the Parsora Formation. Some macrofossils such as *Brachyphyllum, Pagiophyllum* and *Desmiophyllum* reported by number of authors (Sahni and Rao, 1956; Sukh-Dev, 1987; Bose *et al*., 1990; Tarafdar *et al*., 1993) from the Parsora Formation also suggested an early Jurassic age (Mukherjee *et al.*, 2012). However, Shah (2000, 2004) suggested an early Triassic age based on the co-existence of *Glossopteris* and *Dicroidium* on the same bedding plane in Karkati locality but later, it has been confirmed that the Karkati beds belong to Pali Formation (Mukherjee *et al.*, 2012).

It is very striking that the genus *Dicroidium* is the most dominant element in most of the localities of Parsora Formation and the genus never occurs beyond the limits of Triassic. So, the complete extinction of *Dicroidium* signifies the end of Triassic Period. According to Pal *et al.* (2014), amongst the different species of *Dicroidium* known from peninsular India, *D. hughesii* is preponderant throughout the Parsora Formation (Norian-Rhaetian) and occasionally occurs in the Tiki Formation (Carnian). Apart from that *D. zuberi* is also most commonly occurring species of the genus *Dicroidium* in the Tiki and Parsora formations of South Rewa Gondwana Basin though it has recently been recorded from the early Triassic, Panchet Formation (Induan) of Tatapani–Ramkola Coalfield (Chhattisgarh), South Rewa Gondwana Basin (Pal *et al.,* 2014).

As a consequence, the age of the Parsora Formation may not be younger than late Triassic (Norian-Rhaetian). Based on the latest contribution on lithostratigraphy (Mukherjee *et al.*, 2012) and present reassessment of palaeofloristics (from Parsora, Beli, Goira, Chicheria and Dhaurai Hill localities) of the Parsora Formation, it is evident that the age of the formation is younger than early Triassic. Characteristic plant macrofossil assemblage having an overwhelming dominance of *Dicroidium* (Pal, 1985; Pal *et al.*, 2014) and evidence of insect galls (Ghosh *et al.*, 2014) suggest a Norian–Rhaetian age for the Parsora Formation. This is also supported by the typical Norian to Rhaetian palynoassemblage zones from the subsurface borehole data (Vijaya *et al.*, 2012). Based on the present study as well as previous lithostratigraphic and biostratigraphic perception (Mukherjee *et al.*, 2012; Vijaya *et al.*, 2012; Pal *et al.*, 2014; Ghosh *et al.*, 2014) it can be interpreted that in the South Rewa Gondwana Basin, the Parsora Formation (Norian–Rhaetian age) overlies unconformably on the Tiki Formation of Carnian age.

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