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PALYNOLOGICAL INVESTIGATION OF THE LOWER GONDWANA OUTCROP NEAR GOPALPRASAD, ODISHA, INDIA: AN INFERENCE ON THE AGE, PALAEOVEGETATION AND PALAEOCLIMATE

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ABSTRACT

The palynoflora recovered from 9.5 metres thick Dholpahar section along Singda rivulet near Gopalprasad Village, Odisha, India (N20°58′3″ latitude and E85°01′7″ longitude) is distinguished by two distinct palynoassemblages (I and II) on the basis of quantitative and qualitative distributions of various palynotaxa. Palynoassemblage-I is characterized by the dominance of the *Striatopodocarpites* spp. and subdominance of *Faunipollenites varius*. The other stratigraphically significant taxa of this assemblage are *Falcisporites nuthallensis*, *Chordasporites australiensis*, *Stroterspores decorus*, *Lunatisporites pellucidus* and *Weylandites lucifer*. Similarly, Palynoassemblage-II is characterized by the abundance of *Striatopodocarpites* spp. and subdominance of monosaccate genus, *Densipollenites* spp. along with some stratigraphically significant taxa viz., *Stroterspores decorus*, *Striomonosaccites ovatus*, *Falcisporites nuthallensis*, *Chordasporites australiensis*, *Hamiapollenites insolitus*, *Lunatisporites pellucidus* and *Weylandites lucifer*. These two identified palynoassemblages demonstrate the presence of Raniganj/lower Kamthi (upper Permian) sediments exposed near Dholpahar in the lithologically designated Barakar Formation (late lower Permian). Thus, a detailed geological mapping of this area to accurately delimit different Lower Gondwana formations is highly necessitated. The abundance of arborescent vegetation (glossopteridales and coniferales) and scare presence of spores (filicales) suggest that palaeomire was located more in the inland area.

Keywords: Palynostratigraphy, Lower Gondwana, Raniganj, Talcher Basin.

INTRODUCTION

The Talcher Basin, spreading in the Dhenkanal, Angul and Sambalpur districts of the state Odisha, constitutes the south-eastern most part of the Mahanadi Master Basin. This basin mainly occupies the Brahmani River Valley. The first-ever palaeobotanical reports from this basin were carried out by Blanford *et al.* (1859). Feistmantel (1880) reported plant megafossils from the exposed rocks near Gopalprasad Village (the present study area). During subsequent years many palaeobotanical investigations (both megafloral and palynofloral studies) were carried out from several localities of the basin. Palynological studies are reported from the Lower Gondwana formations of Talcher basin (Das, 1958; Bhattacharya *et al.*, 2001; Bharadwaj and Srivastava, 1969a, b; Meena, 2003; Navale and Srivastava, 1971; Tiwari *et al.*, 1991; Tripathi, 1993, 1996, 1997, 2001, 2009; Tripathi and Bhattacharya, 2001; Saxena *et al.,* 2014). The present palynological study was carried out for the fossiliferous horizons of Dholpahar section along Singda rivulet (2 km away from Hingula temple) near Gopalprasad Village (N20°58′3″ latitude and E85°01′7″ longitude) (Fig. 1). A rich megafloral assemblage from the three different fossiliferous horizons of the same Dholpahar Section has also been recorded (Goswami *et al.*, 2018a). It comprises equisetaceous stems, 19 species of *Glossopteris* viz*., G. angustifolia, G barakarensis*, *G. browniana*, *G. churiensis, G. communis, G. indica, G intermittens, G. karharbariensis, G. nakkarea, G. oldhamii, G. recurva, G. retifera*, *G. searsolensis, G. spatulata, G. stenoneura, G. tenuifolia, G. taeniensis, G. vulgaris* and *G. zeilleri, Gangamopteris buriadica* and *Palaeovittaria kurzii* of the order Glossopteridales. The aims of this study are to (a) construct the palynostratigraphy of the Lower Gondwana formations of the Talcher Basin based on palynomorphs and (b) decipher the palaeoenvironment and palaeovegetation based on megafloral and palynofloral assemblages.

GEOLOGICAL SETTING

The Talcher Basin is delimited by latitudes 20^0 53′ and 21^0 12′ and longitudes 84^0 20′ and 85^0 23′ (Fig. 1) with an aerial extent of over 1800 sq. km. The strike length of the basin in east-west direction is about 80 km and the width in north-south direction is about 26 km. This basin demonstrates a northwesterly plunging synclinal structure, which closes on the east with younger horizons outcropping towards west. The Precambrian-Permian boundary is manifested by WNW- ESE trending faults in the north and an unconformity is exposed in the south. The regional strike of the Permian-Triassic sedimentary rocks of this basin is more or less east-west but varies from ENE-WSW to ESE-WNW (Raja Rao, 1982). The Permian-Triassic Gondwana sediments of this Basin belong to the Talchir, Karharbari, Barakar, Barren Measures, lower Kamthi/Raniganj, and upper Kamthi formations. The stratigraphic nomenclature of the Talcher Basin is depicted in Table 1 (Sastry *et al.*, 1977; Bhattacharya *et al.*, 2002; Goswami and Singh, 2013; Goswami *et al.*, 2018a).

A significant portion of the present investigated area in and around Dholpahar section along Singda rivulet near Gopalprasad

Village is covered by the Barakar Formation, which overlies Karharbari Formation. Besides, some exposures of alluvium have also been observed. Barakar sediments include fine to coarse-grained feldspathic sandstone, gray and carbonaceous shales, siltstone, silty shale (Fig. 2). This section has about 9.5 metres thickness. Singda rivulet (a tributary of Brahmani River) constitutes the main drainage system of this area. The overall stratigraphic succession of the investigated area is given below.

Alluvium	2m
Sandstone	1m
Siltstone	0.5m
Siltyshale (GA)	0.5 m
Gray Shale (GB, GC)	0.8m
Sandstone	2m
Siltstone	0.7m
Siltyshale (GD)	1m
Carbonaceousshale (GE)	0.3m
GrayShale (GF)	0.7m
Base notexposed	

MATERIALS AND METHODS

Altogether 6 samples (GA, GB, GC, GD, GE and GF) (Fig. 2) were collected from the fossiliferous horizons of the studied section along Singda rivulet near Gopalprasad Village (N20°58′3″ latitude and E85°01′7″ longitude) to carry out palynostratigraphic studies. The samples were crushed into small pieces (2–3 mm in size) and were treated with 40% hydrofluoric acid (HF) to dissolve siliceous component and then washed with water several times to make the samples acid free. The resultant demineralized samples were then treated with commercial nitric acid (HNO_3) for 3–4 days with frequent addition and stirring of fresh HNO_3 (63.09%) from time to time for digestion of humic matter. Each sample was examined under the microscope at each step of maceration before further treatment. After thorough washing with water, the samples were treated finally with 10–20% potassium hydroxide (KOH) to get clear palynomorphs. Palynomorphs were concentrated, constituting final residue and slides were prepared from a few drops of the final residue by mounting in Canada balsam with the help of poly-vinyl chloride (PVC). All slides were scanned under Olympus BX62 microscope and photographed with DP25 camera. These slides were stuck in the museum of the Department of Geology, Ravenshaw University, Odisha. For quantitative analysis, a total of 200 spores/pollen grains were counted for each sample. Palynofloral studies have been carried out at the Birbal Sahni Institute of Palaeosciences, Lucknow, India.

PALYNOLOGY

Out of 6 samples, only three samples have the countable number of pollen grains. Quantitative distribution of different types of the palynoflora has been presented in the histogram (Fig. 3). Stratigraphically significant taxa of the recovered palynoassemblages are shown in Plate I. Based on the quantitative and qualitative distributions of various palynotaxa, two distinct palynoassemblages (I and II) have been identified in the studied sequence from the Gopalprasad area, which are as follows:

Palynoassemblage-I is characterized by the dominance of the *Striatopodocarpites multistratitus*, *S. decorus, S. diffusus* (52.5-56.3%) and subdominance of *Faunipollenites varius* (27.3-29.3%) along with some stratigraphically significant taxa viz., *Falcisporites nuthallensis* (0.4- 2.45%), *Chordasporites australiensis* (0-0.4%), *Strotersporites decorus* (2.45-5%), *Lunatisporites pellucidus* (1-9.6%), *Weylandites lucifer* (0-0.5%). The other recorded taxa of this palynoassemblage are *Osmundacidites* sp. (0-1.26%), *Parasaccites* sp. (0-0.4%), *Densipollenites invisus* (1.26-4.4%), *Scheuringipollenites maximus* (0.4-0.5%), *Striatites tentulus* (0.5-1.26%), *Striapollenites* sp. (0-0.4%) and *Crescentipollenites* sp. (0.4-1.96%). This palynoassemblage has been identified in sample GD and GF (Fig. 2).

Lithostratigraphic distribution: Barakar Formation

Age: Late Permian (Raniganj), Jha *et al.*, 2018.

Comparison: This palynoassemblage compares well with the *Striatopodocarpites- Faunipollenites* Assemblage Zone (Table-4; Zone V-A) or *Gondisporites raniganjensis* zone of the Damodar Basin (Tiwari and Tripathi, 1992). The Palynoassemblage-I compares well with Palynoassemblage-E (Gundala: Jha and Aggarwal, 2011); Palynozone-4 (Mailaram: Jha and Aggarwal, 2012); Palynozone-5 (Lingala-Koyagudem coal belt: Aggarwal and Jha, 2013) and Palynoassemblage-V (Chintalapudi sub-basin: Jha *et al.*, 2018) of the Godavari Valley Coalfield. Besides Godavari Valley Coalfield, Palynoassemblage-I is also akin to the Raniganj Formation of the Damodar Basin (Bharadwaj *et al.*, 1979; Tiwari and Singh, 1986); Pali Formation of South Rewa Basin (Ram-Awatar *et al.*, 2004); Palynozone-2 of IB River Coalfield (Meena, 2000); Palynoassembalge- E of the Son Valley (Tiwari and Ram-Awatar, 1989); Raniganj Formation of the IB River and Talchir Coalfields (Tiwari *et al.*, 1991; Tripathi, 1997) and palynoassemblage of the Iria Valley Coalfield (Srivastava and Kar, 2001).

Palynoassemblage-II is demarcated by the abundance of striate bisaccate- *Striatopodocarpites multistratitus*, *S. subcircularis, S. diffusus* (43.5%) and subdominance of monosaccate genus- *Densipollenites indicus, D. invisus*, *D. magnicorpous* (27%) along with some stratigraphically significant taxa viz., *Strotersporites decorus* (2.9%), *Striomonosaccites ovatus* (0.4%), *Falcisporites nuthallensis* (5%), *Chordasporites australiensis* (0.8%), *Hamiapollenites insolitus* (0.8%), *Lunatisporites pellucidus* (6.2%), *Weylandites lucifer* (0.8%). The other recorded taxa of this palynoassemblage are *Microbaculispora gondwanensis* (0.4%), *Osmundacidites* sp. (0.8%), *Parasaccites obscurus* (0.4%), *Faunipollenites* sp. (8.2%), *Striatites tentulus*, *Striatites* sp. (2%) and *Crescentipollenites globosus* (0.4-1.96%). This palynoassemblage has been identified in sample GC only (Fig. 2).

Lithostratigraphic distribution: Barakar Formation

Age: Late Permian (Raniganj), Jha *et al.*, 2018.

Comparison: Palynoassemblage-II compares well with the *Striatopodocarpites- Densipollenites* Assemblage Zone (Table-4; Zone V-C) or *Densipollenites magnicorpus* Assemblage zone of the Damodar Basin (Tiwari and Tripathi, 1992) and Palynozone-6 (Mailaram: Jha and Aggarwal, 2012); Palynozone-8 (Budharam: Srivastava and Jha, 1995) and Palynoassemblage-VII (Chintalapudi sub-basin; Jha *et al.*, 2018) areas of the Godavari Valley Coalfield in having the dominance of *Striatopodocarpites* spp. along with *Densipollenites* spp. The *Densipollenites* assemblage zone is well known from the other Lower Gondwana basins of India such as Son Valley (Tiwari

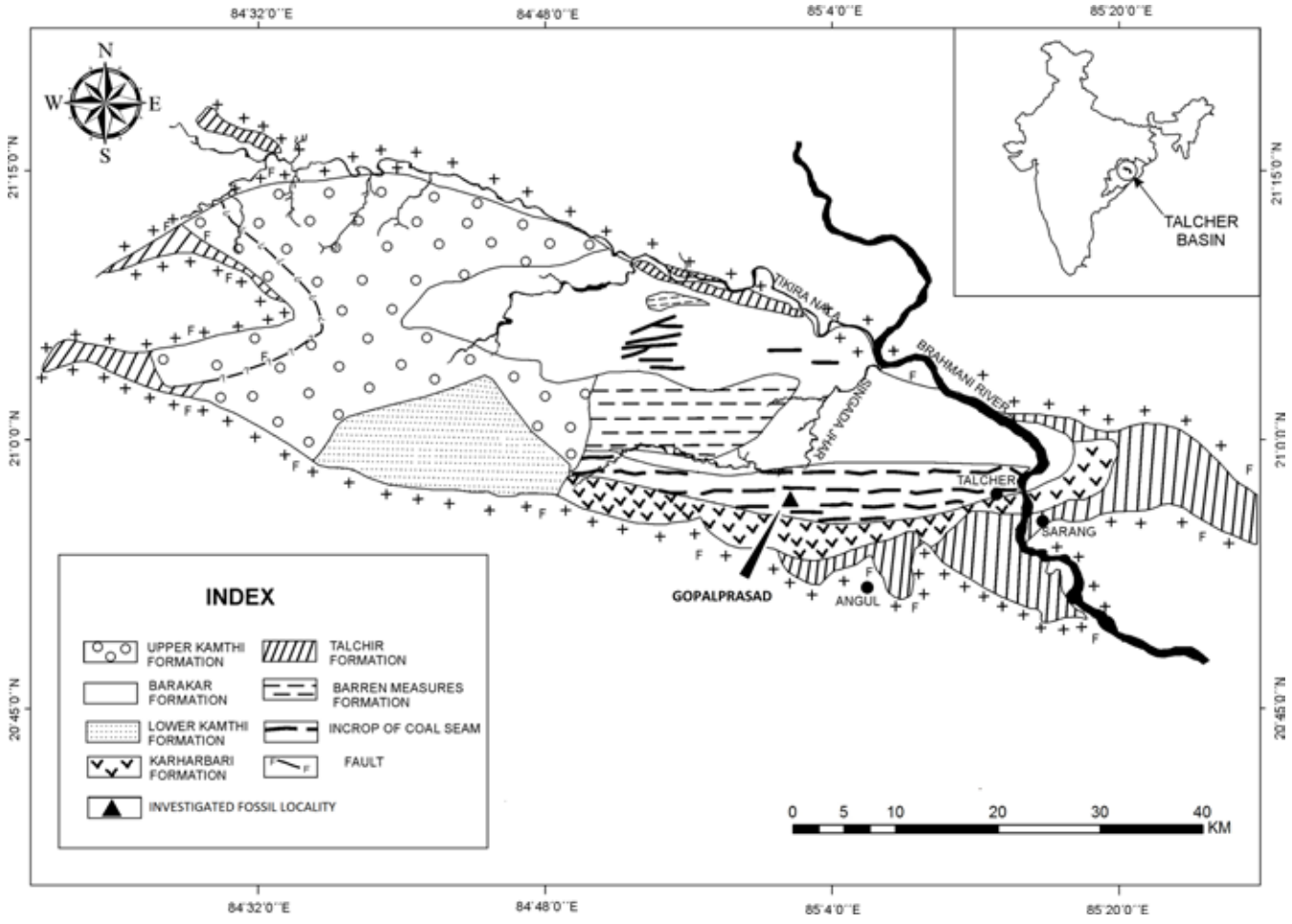

Fig. 1. Geological map of the Talcher Basin showing the investigated fossil locality (Dholpahar Section near Gopalprasad).

and Ram-Awatar, 1989); Damodar Basin (Srivastava *et al.*, 1997; Murthy *et al.*, 2015); Rajmahal Basin (Tripathi *et al.*, 2010); Satpura Basin (Bharadwaj *et al.*, 1978); Mahanadi Basin (Tripathi, 1997; Chakraborty, 2003); South Rewa Basin (Ram-Awatar *et al.*, 2005); Wardha Valley (Mahesh *et al.*, 2007) and the Kamptee Coalfield (Srivastava and Bhattacharyya,1996).

DISCUSSIONS AND CONCLUSION

Age demarcation based on palynofloral diversity

Striate bisaccates show fairly good percentages in Indian Lower Gondawna (lower Barakar) and sustain as a dominant palynofloral component in the late Permian (Raniganj/lower Kamthi). Resultantly, stratigraphically significant taxa play a very important role while identifying the palynoassemblages in the late Permian succession. The quantitative estimation of different palynoflora shows marked changes in mioflora from the early Permian to late Permian. As the Palynoassemblages I-II are distinguished by the abundance of *Striatopodocarpites* spp., *Faunipollenites varius*, *Densipollenites* spp. along with stratigraphically significant taxa viz., *Striomonosaccites ovatus*, *Falcisporites nuthallensis*, *Chordasporites australiensis*, *Strotersporites decorus*, *Lunatisporites pellucidus*, *Hamiapollenites insolitus* and *Weylandites lucifer.* Hence, late Permian age has been assigned to these palynoassemblages.

Presently studied palynoassemblages (Raniganj palynoflora) have been identified in the sediments exposed near Dholpahar, which is currently mapped as the Barakar Formation (late lower Permian). As palynology advocates the presence of late Permian sediments (lower Kamthi/Raniganj Formation) in this area, this might be erroneously mapped as the Barakar Formation. Thus, a detailed geological mapping should be attempted to delimit more accurately the distribution of the different Lower Gondwana formations in this basin.

Botanical affinity

The palynomorphs recovered from the three samples reveal the palynocomposition, which consists of 17 genera and 26 species belonging to Glossopteridales (10 taxa represented by *Faunipollenites varius, Faunipollenites* sp.*, Striatopodocarpites multistriattus, S. decorus, S. diffuses, S. subcircularis, Scheuringipollenites maximus, Striatites tentulus, Striatites* sp. and *Striapollenites* sp.), Coniferales (8 taxa represented by *Crescentipollenites globosus, Crescentipollenites* sp., *Chordasporites australiensis, Hamiapollenites insolitus, Lunatisporites pellucidus, Parasaccites obscures, Parasaccites* sp. and *Strotersporites decorus*), Cordaitales (4 taxa namely, *Densipollenites indicus, D. invisus, D. magnicorpous and Striomonosaccites ovatus*), Filicales (2 taxa, viz., *Microbaculispora gondwanensis* and *Osmundacidites* sp.) and Ginkgoales (2 taxa such as *Falcisporites nuthallensis* and

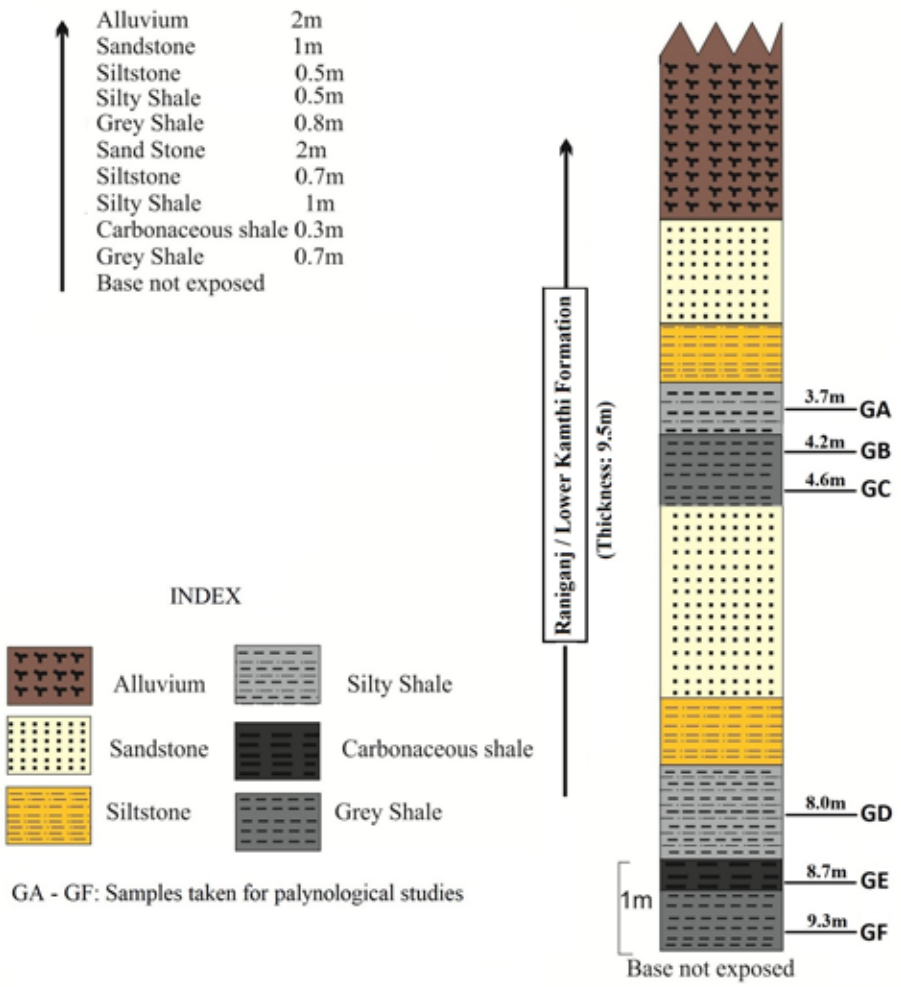

Fig. 2. Geological section along with the investigated fossil locality of Dholpahar Section near Gopalprasad.

Weylandites lucifer) (Table 2).

Palynoassembalge-I depicts that the palaeovegetation during the late Permian (during the deposition of Raniganj sediments) was dominated by the glossopteridales (*Striatopodocarpites* spp., *Faunipollenites* spp., *Striatites* spp., *Scheuringipollenites* sp., *Striapollenites* sp.) (81.86-86.70%) and sub-dominated by coniferales (*Crescentipollenites* sp., *Chordasporites* sp., *Lunatisporites* sp., *Parasaccites* sp. and *Strotersporites* sp.) (5.81-15%). Cordaitales were very less (1.26-4.40%), which were represented by *Densipollenites* spp.,

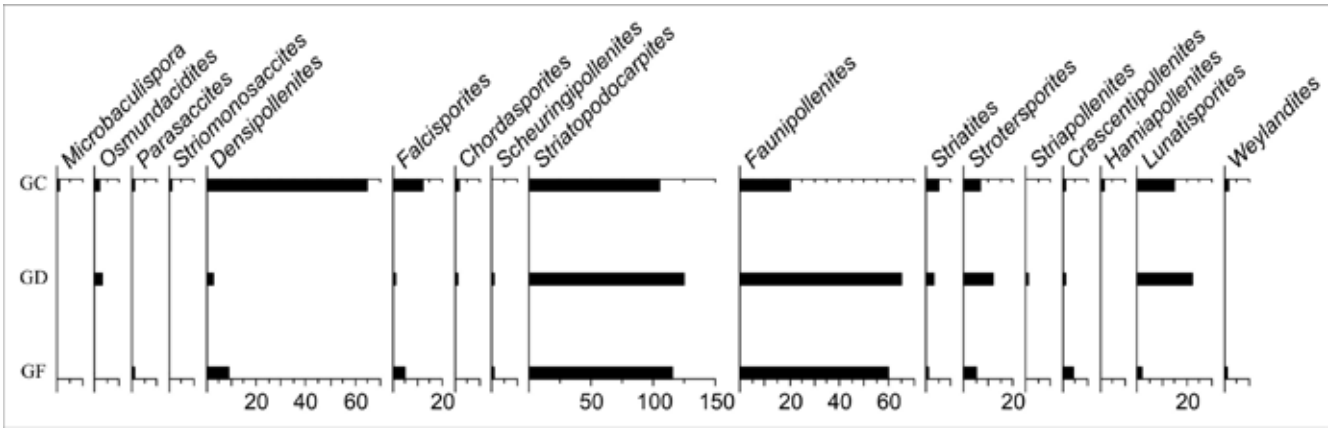

Fig. 3. Histogram showing frequency distribution of the Palynomorphs recorded (genus level) from the studied section of Gopalprasad Village.

Table 1. Stratigraphic nomenclature of the Talcher Basin, Odisha (after Manjrekar *et al*., 2006; Goswami and Singh, 2013; Goswami *et al*., 2018).

Age	Formation/ Member	Lithology and fossil content	Thickness
Recent		Alluvium and laterite	
Triassic	Upper Kamthi	***Upper bed (Late Triassic):*** Ferruginous, hard and quartzitic sandstones, bands of compact brown, grey and yellow shales and clasts of lavender and creamy white shales. Megafloral assemblage is dominated by *Dicroidium, Lepidopteris, Elatocladus, Yabiella* and *Desmiophyllum.* Palynoassemblage includes *Brachysaccus, Rimaesporites, Samaropollenites* and *Callialasporites.*	
		Lower bed (Early Triassic): Medium-grained, cross-bedded ferrugineous yellowish white sandstones, alternating with thick bands of red and grey shales. Megafloral assemblage is dominated by *Glossopteris* with few *Neomariopteris, Lepidopteris* and *Dicroidium* (?). Palynoassemblage includes *Striatopodocarpites, Satsangisaccites, Falcisporites, Weylandites, Muraticavea, Lundbladispora, Arcuatipollenites, Playfordiaspora* and *Alisporites*	250 + meters
Late Permian	Lower Kamthi= Raniganj	Medium to coarse grained, pebbly cross-bedded ferruginous sandstones, clasts of greenish-white and grayish-white shales, carbonaceous and grey shales, pink clays. Megafloral assemblage is dominated by medium and broad mesh forms *Glossopteris* species with plenty of ferns and arthrophytes. Palynoassemblage is dominated by *Striatopodocarpites, Faunipollenites* and *Crescentipollenites.*	
Middle Permian	Barren Measures	Coarse to medium grained greenish grey feldspathic sandstones with shreds and lenses of chocolate coloured clay, micaceous siltstone, dark grey shale, carbonaceous shale, purple brown shale and clay ironstone. Palynofloral assemblage is dominated by *Densipollenites* and *Striatopodocarpites*	317+ meters
Early Permian	Barakar	Fine to coarse grained feldspathic whitish sandstones, siltstone, grey shale, sandy shale, fireclay and coal seams with polymictic conglomerate at the base. Megafloral assemblage is dominated by narrow and medium mesh forms *Glossopteris* species with few ferns and arthrophytes. Palynoassemblage is dominated by *Scheuringipollenites, Faunipollenites* and *Striatopodocarpites.*	600 meters
Early Permian	Karharbari	Medium to Coarse grained whitish arkosic sandstones, carbonaceous shale, grey shale and coal seams. Megafloral assemblage is dominated by *Buriadia*, *Gangamopteris, Euryphyllum* and *Noeggerathiopsis.* Palynoassemblage is dominated by *Parasaccites, Microbaculispora* and *Brevitriletes*	270 meters
Early Permian	Talchir	Diamictites, rhythmites, turbidites, conglomerate, fine to medium-grained greenish sandstones, olive coloured needle shales, turbidite, tiliets and tilloids etc. Megafloral assemblage comprises *Noeggerathiopsis*, equisetaceous stems, *Gangamopteris, Arberia* and *Ottokaria* etc. Palynoassemblage is dominated by *Plicatipollenites, Potonieisporites* and *Caheniasaccites.*	170 meter +
		---------- unconformity----------	
Precambrian		Granites, gneisses, amphibolites, migmatites, quartzite and pegmatites etc.	

whereas filicales (*Osmundacidites* sp., 0-1.6%) and ginkgoales (*Falcisporites,* 0.4 – 2.45%; *Weylandites,* 0-0.5%) were rare in occurrence (Balme, 1995; Jasper *et al.*, 2006).

Palynoassemblage-II demonstrates that the then vegetation during the deposition of Raniganj sediments was represented by the dominance of glossopteridales (*Striatopodocarpites* spp., *Faunipollenites* spp., *Striatites* spp.) (53.7%) and sub-dominance of cordaitales (*Densipollenites* spp. and *Striomonosaccites* sp.) (27.4%). Coniferales were very less (11.5%), which were represented by *Crescentipollenites* sp., *Chordasporites* sp., *Hamiapollenites* sp., *Lunatisporites* sp., *Parasaccites* sp. and *Strotersporites* sp., whereas filicales (*Microbaculispora* sp. and *Osmundacidites* sp.; 1.2%) and ginkgoales (*Falcisporites,* 5%; *Weylandites,* 0.8%) were rare in occurrence (Balme, 1995, Jasper *et al.*, 2006).

Palaeovegetation

The megafloral assemblage of this section consists of equesetaceous stems, 19 species of *Glossopteris* viz., *G. angustifolia, G barakarensis*, *G. browniana*, *G. churiensis, G. communis, G. indica, G intermittens, G. karharbariensis, G. nakkarea, G. oldhamii, G. recurva, G. retifera*, *G. searsolensis, G. spatulata, G. stenoneura, G. tenuifolia, G. taeniensis, G. vulgaris* and *G. zeilleri, Gangamopteris buriadica* and *Palaeovittaria kurzii* (Goswami *et al.*, 2018a). The megafloral assemblage recovered from Dholpahar section depicts that forest around Gopalprasad area was dense and swampy growing in low lying river valleys and the vegetation was lush green subjugated by arborescent deciduous trees bearing *Glossopteris* foliage with some equisetales (Singh *et al.*, 2005, 2006a, b, c, 2007, 2011,

Table 2. List of species recorded from the Dholpahar section, Gopalprasad village.

Identified palynomorphs	Botanical affinity (Balme, 1995; Gould and Delevoryas, 1977; Jasper *et al*., 2006)
Crescentipollenites globosus (Maithy) Jha, 1996	Coniferales
Chordasporites australiensis de Jersey, 1962	Coniferales
Densipollenites indicus Bharadwaj, 1962	Cordaitales
D. invisus Bharadwaj and Salujha, 1964	Cordaitales
D. magnicorpous Tiwari and Rana, 1981	Cordaitales
Faunipollenites varius Bharadwaj 1962	Glossopteridales
Falcisporites nuthallensis Clarke, Balme, 1970	Ginkgoales
Hamiapollenites insolitus Bharadwaj and Salujha, 1964	Coniferales
Lunatisporites pellucidus (Goubin, 1965) Maheshwari and Bnaerji, 1975	Coniferales
Microbaculispora gondwanensis Bharadwaj, 1962	Filicales
Osmundacidites sp.	Filicales
Parasaccites obscures Tiwari, 1965	Coniferales
Parasaccites sp.	Coniferales
Striatopodocarpites multistriatus Jha, 1996	Glossopteridales
S. decorus Bharadwaj and Salujha, 1964	Glossopteridales
S. diffuses Bharadwaj and Salujha, 1964	Glossopteridales
S. subcircularis Sinha, 1972	Glossopteridales
Striomonosaccites ovatus Bharadwaj, 1964	Cordaitales
Scheuringipollenites maximus (Hart) Tiwari, 1973	Glossopteridales
Striatites tentulus Tiwari, 1965	Glossopteridales
Striatites sp.	Glossopteridales
Strotersporites decorus Bharadwaj and Salujha, 1964	Coniferales
Striapollenites sp.	Glossopteridales
Weylandites lucifer (Bharadwaj and Salujha) Bharadwaj and Dwivedi, 1981	Ginkgoales

2012; Meena and Goswami, 2004). Most of the *Glossopteris* plants were arborescent trees except a few herbaceous plants. *Palaeovittaria* and *Gangamopteris* had not formed conspicuous vegetation like *Glossopteris*. Palynomorphs also reveal that the forest is dominated by glossopteridales and sub-dominated by coniferales and cordaitales. It also indicates that filicales and ginkgoales were of localised occurrence.

Palaeoclimate

Megafloral assemblage demonstrates stable climatic conditions and the dominance of medium-sized *Glossopteris* leaves having lanceolate shape, entire margin, acute cuneate/ tapering bases and acute apices explicitly reveals a warm humid temperate environment with abundant rainfall and adequate light intensity (Goswami, 2002, 2006, 2007, 2008; Goswami and Singh, 2010; Goswami *et al.,* 2006a, b, c, 2018b). Thus, there was a warm temperate climate with an appreciable amount of humidity in this area.

Glossopterids represent mesophilous palaeoenvironment and proliferate in lowland peats, while conifers were carried out from more far-away parts to the mires and are measured to be extrabasinal elements which typically show numerous adaptations for subsistence in drier habitats (Knoll and Nicklas, 1987). Cordaites also grow up in the mesophilous palaeoenvironment and palaeoecologically they inhabited in well-drained low land areas (Taylor and Taylor, 1993).

Based on botanical affinity, the pre-eminence of glossopteridales and contributory presence of cordaitales, coniferales and scare presence of spores in the present palynoflora represents a warm and humid climate (Guerra-Sommer *et al.*, 1983) in a telmatic environment (forest moor).

Tiwari and Tripathi (1987) proposed 11 climatic suits during the deposition of the Lower Gondwana sediments on the basis of morphology and cumulative abundance of palynomorphs. Palynoassemblage-I lies in suite 8 and Palynoassemblage-II

EXPLANATION OF PLATE I

Fig. 1. ***Osmundacidites*** sp., GC_1_M23-4, Fig. 2. ***Falcisporites nuthallensis***, GC_1_D26-1, Fig. 3. ***Striatopodocarpites*** sp., GC_1_G23-4, Fig. 4. ***Chordasporites australiensis***, GC_1_Q34, Fig. 5. ***Densipollenites invisus***, GC_1_Q35-4, Fig. 6. ***Strotersporites decorus***, GD_1_N37-3, Fig. 7. ***Hamiapollenites insolitus***, GC_3_K_G31-3, Fig. 8. ***Striatopodocarpites multistriatus***, GC_3_K_H41-1, Fig. 9. ***Faunipollenites varius***, GD_3_Q61-3, Fig. 10. ***Lunatisporites pellucidus***, GD_3_S54-2, Fig. 11. ***Lunatisporites pellucidus***, GC_3_K_M28, Fig. 12. ***Weylandites lucifer***,GC_2_Q27, Fig. 13. ***Densipollenites indicus***, GC_1_N46-3, Fig. 14. ***Striatites tentulus***, GC_2_R40-1, Fig. 15. ***Falcisporites nuthallensis***, GC_1_O29.

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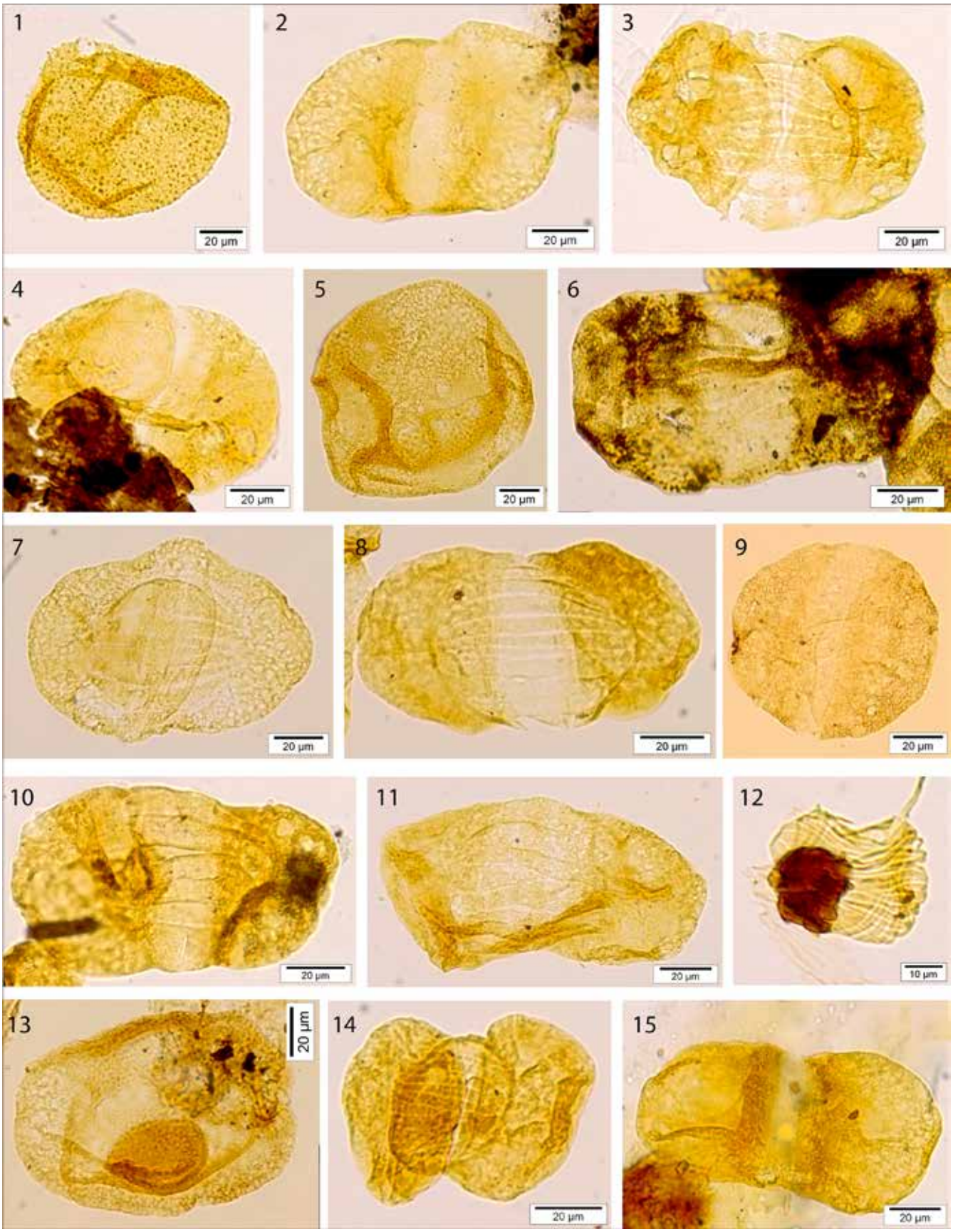
Plate I



lies in suite 9. Suite 8 and suite 9 exhibits more or less similar climate but the abundant presence of *Densipollenites* spp. in suite 9 indicates a change in the climate. Palynoassemblage-I (abundance of glossopteridales along with subdominance of coniferales) represents more humid climate as compared to palynoassemblage-II (abundance glossopteridales and sub-dominance of cordaitales), which is also advocated by the presence of a thick succession of shale (2m) during the deposition of Palynoassemblage-I (Fig. 2). The presently studied palynoassemblages (I and II) demonstrate warm, humid (high) temperate climate with sufficient water supply, which is also inferred on the basis of palaeoenvironmental model based on megafloral assemblages.

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