INTRODUCTION

Eistmantel (1880) first proposed the classification of Gondwana rocks by suggesting a tripartite division of the rocks of India on the basis of floral evidences. Subsequently the classification was supported by Vredenburg (1914), Wadia (1926), Saksena (1952, 1974) and Lele (1964). Bose (1966), Roy Choudhuri et al. (1973), Acharyya et al. (1977), and Sastry et al. (1977) expressed similar views on the classification of Gondwana rocks. Three floral assemblage zones in the Indian Gondwana were identified by Shah et al. (1971).

The Lower Gondwana flora is commonly known as Glossopteris flora on the basis of rich assemblage of Glossopteris plant fossils (Shah et al. 1971). The Lower Gondwana basins in the Indian Peninsula occupy well defined linear belts and occur as isolated patches of coal measures in the Rajmahal coalfields, exposed along the western flanks of the north-south trending Rajmahal Hills, in the east-west trending Damodar-Koel valley basins and Satpura basin, north-west-southeast trending Son-Mahanadi valley and Pranhita-Godavari valley basins respectively, all of which tend to coverage towards the heart of the Peninsula. In extra Peninsular region, detached exposures of Lower Gondwana are known from the frontal zones of the Eastern Himalayan Foothills, window zone of Sikkim and the Tethyan domain of Kashmir, Sputi and Sikkim.

The Lower Gondwana sedimentation was conducted during Early Permian by widespread glacial advances as evidenced by the presence of boulder beds at the base of the 6-7 km thick Gondwana succession. This resulted in deposition of a varying pile of glacial, glacio-lacustrine and fluvo-glacial sediments. With the retreat of the cold glacial age, the irregular topography of the Indian Peninsula was filled in by swamps rich in vegetative matter, emerged due to the amelioration of the climate that continued till the end of the Permian. The rich vegetation ultimately got transformed into thick coal seams. The environmental facies however, changed with the gradual change of climate through the entire sequence of coal deposition proceeded by the glacial activity during Talchir Formation in Early Permian. Though the Lower Gondwana sediments are said to be chiefly of fluviatile or lacustrine origin, evidences of thin marine transgression are known to occur in Peninsular India at Umaria and Manendragarh in Madhya Pradesh, Bap and Badhaura in Rajasthan and Daltonganj in Bihar during Early Permian times. In extra Peninsular India, Permian marine incursions are reported from Abor Hills, Dikrong valley and Subansiri in Eastern Himalaya, Khamgaon and Wak in west Sikkim, Salt Range and Kashmir (Ghosh and Banerjee 1987, Singh I.B. 1981). The vast coal deposits of Peninsular India are mostly confined to the Barakar and Raniganj Formations of Damuda Series and also Karharbari Formation of Talchir Series while Talchir and Kulti Formation (Barren Measure - Sastry et al. 1977) are devoid of any reputed coal deposits. Most of the thick coal strata in the different coal fields of Indian Peninsula belong mainly to Barakar Formation of Lower Permian and Raniganj Formation of Upper Permian age. Raniganj Formation provides the dominant assemblage of Glossopteris flora among all the Formations of Indian Lower Gondwana.

The vegetation that flourished for about fifty million of years during Lower Gondwana is the major source of coal in India. Both megaflora and palynoflora were extensively studied in Lower Gondwana Sediments of Raniganj Formation by several authors (Banerjee 1987, 1994; Tiwari 1999). It is well known that floral assemblages of the Indian Lower Gondwana sequence whether macroscopic mega plant fossils or microscopic spore-pollen, are extremely useful in understanding environment of deposition, classification, correlation and also for...
assigning age of the sediments due to the scarcity of faunal evidence.
Recent studies on the Glossopteris flora from all the continents of Lower Gondwana including India have revealed the fact that further exhaustive exploration of the flora is essential to understand not only the diverse pattern of the flora and the strategic phases in the evolution of plant groups but also the significant role of the flora in geological investigations including palaeogeography, plate tectonic, coastal area identification, etc.
For this purpose, present work has been taken up in Sonepur-Bazari area, a second biggest Open Cast mine of the Eastern Coalfield Ltd. to investigate the palynofloral assemblage and its depositional environment as the area is totally unexplored in this regard.

MATERIAL AND METHOD

Study Area
Sonepur-Bazari combined open cast project of Eastern Coalfield Limited (ECL) is situated between two villages namely Sonepur and Bazari in the eastern part of Raniganj coalfields in Burdwan district (Fig. 1) of West Bengal (latitudes 23°40'00" N and 23°43'06" N, longitude 87°11'14" E and 87°17'42" E). The area is 14 km away from G. T. Road, 30 km away from Asansol and 35 km away from Durgapur (source from Eastern Coalfields Limited, GOI).

Material
Sediments are collected from the shale layer between the coal seam numbers V and VI (Fig. 2) of bore hole (BZ-070). The samples are catalogued properly and kept at repository of Pteridology-Palaeobotany Section, Department of Botany, University of Kalyani.

Method
About 10 gm from each sample were first treated with 40% hydrofluoric acid (HF) for a minimum period of 24 hours to dissolve and remove silica and hence concentrate the organic matters. The samples were then macerated by freshly prepared Schulze solution (concentrated HNO$_3$;KClO$_3$;3:1) and were then treated with 10% potassium hydroxide (KOH) solution to make the palynomorphs free. The treated samples were again thoroughly washed with distilled water and centrifuged at 3000 rpm for 15 minutes. Then the samples were slide fixed in polyvinyl alcohol and mounted using DPX and observed under the microscope (Leitz Laborlux-D). Photomicrographs were taken from the suitable preparation and subsequently magnified.
Microfloristic composition of each of the macerated sample was determined through the identification of taxa using original diagnostic characteristics with illustrations of genera and species in Genera File of Jansonius and Hills (1976) and available literatures including paleo-databank. The identification of taxa and differentiation of genera and species were made after thorough study of prepared slides kept in the repository of Pteridology-Palaeobotany Section, Department of Botany, University of Kalyani.

RESULT

Twelve species of palynomorphs belonging to nine genera have been identified through the maceration of samples. Among the recovered palynomorphs both the striate and non striate disaccate grains are present along with monocolpate grains of Gnetaceae pollenites sinuosus (Fig. 5) but occurrence of trilete spores are totally absent. Overall dominance of striate disaccates (Figs. 12-14) along with fairly consistent and occasional dominance of non striate disaccates is clearly recorded in the present assemblage. Non-striate disaccates mainly genus Scheuringipollenites, Primuspollenites, Cuneatisporites, Rhizomospora, Aurangapollnites and Ranigangisaccites are documented from the assemblage. The frequency distribution of each of the taxa is presented graphically in Fig. 15. Brief descriptions of each of the miospore are given below:

Non Striate Grains
Aurangapollnites gurturiensis Sriv.: Bilateral, diploxylonoid, size range 75-99 µm × 30-60 µm, central body oval intra-micropunctate, saccus hemispherical, distal sulcus broad, finely intrareticulate (Fig. 3).
Cuneatisporites sp.: Bilateral, diploxylonoid (sac larger than central body), size range 75-95 µm × 54-69 µm, central body vertically oval, intramicoreticulate, saccus hemispherical, distal zone of saccus attachment associated with semilunar fold, laterally sacci coming very close to each other, sulcus biconvex broad, intrareticulate (Fig. 4).
Gnetaceae pollenites sinuosus (Balme & Henn) Bhar: Fusiform, two longitudinal crescentic folds running full length and converging at extremities, exine laevigate, longitudinally sparsely striated, occasionally branched (Fig. 5).
Scheuringipollenites maximus (Hart) Tiw: Circular to subcircular pollen grains, size 75-165 µm, central body thin, indistinct, subcircular to broadly oval, saccus hemispherical, distally very close to each other in the median region, forming an ill-defined sulcus, reticulation coarse to medium meshed (Fig. 6).
Primuspollenites obscurus Tiw: Bilateral, diploxylonoid, size 110-145 µm × 60-85 µm, central body outline indistinct, vertically oval, proximally reticulosoid striations, saccus subhemispherical, sulcus convex, coarsely intrareticulate (Fig. 7).
Primuspollenites levis Tiw: Bilateral, diploxylonoid, size 90-160 µm × 60-150 µm, central body vertically oval, proximally bearing reticulosoid striations, saccus hemispherical, distal attachment distinct, full length;
sulcus convex accompanied by characteristic thickening, coarsely reticulate (Fig. 8).

*Primuspollenites densus* Tiw: Bilateral, diploxyloido, size 114-153 µm × 75-105 µm, central body dense, vertically oval, proximally bears reticuloid striations, saccus hemispherical, distal attachment well defined, full length, sulcus narrow, accompanied by thickenings, finely intrareticulate (Fig. 9).

*Raniganjiasaccites ovatus* Kar: Bilateral, diploxyloido, size 81-120 µm × 45-75 µm, central body subcircular to oval, intra-microreticulate, saccus hemispherical, sulcus distinct broad, coarsely intrareticulate (Fig. 10).

*Rhizomaspora indica* Tiw: Bilateral, monosaccoidal, size 93-154 µm × 60-75 µm, central body circular to subcircular, dense proximally bearing reticuloid striations, saccus sub-spherical invading central body on proximal side, many radiating folds of saccus continuing from body subequatorial region into saccus, sulcus ill-defined, sccci laterally deeply notched or continuous, intrareticulate (Fig. 11).

**Striata Grains**

*Striatopodocarpites magnificus* Bharad & Sal: Bilateral, diploxyloido or central body and saccus of same height, size 120-150 µm × 66-90 µm, central body circular to subcircular, proximally horizontally striated, intra-microreticulate, saccus hemispherical, sulcus broad, intrareticulate (Fig. 12).

*Striattites obtusus* Bharad. & Sal.: Bilateral, diploxyloido, size 75-105 µm × 54-75 µm, central body thick, vertically oval, with a thin marginal ridge, proximally horizontally striated with few vertical partitions, microverrucose. Saccus sub-spherical to hemispherical, sulcus convex, medially intrareticulate (Fig. 13).

*Striattites ornatus* Venk. & Kar: Bilateral, diploxyloido, size 60-90 µm × 36-54 µm, central body vertically oval, proximally horizontal, striated, infrastructure, saccus sub-spherical to hemispherical, sulcus narrow, infrareticulate (Fig. 14).

Fig. 1. Map of Sonepur-Bazari Coalfield showing study area - marked in circle. (Courtesy: Eastern Coalfields Limited, GOI).

Fig. 2. Lithological column of bore hole BZ-070. (Courtesy: Eastern Coalfields Limited, GOI).
Fig. 3-14. Recovered palynomorphs (3) Aurangapollenites gurturiensis (4) Cuneatisporites sp. (5) Gnetaceae pollenites sinuosus (6) Scheuringipollenites maximus (7) Primuspollenites obscurus (8) Primuspollenites levis (9) Primuspollenites densus (10) Raniganjiasaccites ovatus (11) Rhizomaspora indica (12) Striatopodocarpites magnificus (13) Striatites obtusus (14) Striatites ornatus.

Fig. 15. Frequency distribution of the recovered palynomorphs.
DISCUSSION AND CONCLUSION

Palynomorphs are being widely used as effective tools in high resolution palynostratigraphic zonation, correlation and age determination of the Lower Gondwana sedimentary sequence of the Perm-Carboniferous age in several basins of the Gondwanaland (Banerjee and D'Rozario 1990; Scotese et al. 1999; Beri et al. 2010). Several schemes of palynostratigraphic zonation have been proposed for the Indian Lower Gondwana sedimentary sequence. In the Indian Gondwana sequence, the Talchir Series (Talchir and Karharbari Stages) of the Early Permian is characterized by a dominance of radial monosaccates, like Parasaccites, Plicatipollenites along with laevigate triletes, like Callumispora, etc. whereas, lower part of the Damuda Series, the Barakar Stage of the middle and late Early Permian is dominated by non-striate disaccates, like Scheuringipollenites. The Kulti/Barren Measures Stage of Middle Permian age is dominated by dense bodied monosaccate pollen, like Densipollenites along with other saccates, but the predominance of striate disaccates, like Faunipollenites, Striatopodocarpites, Striattites, etc. are the characteristics of Raniganj Stage of the Upper Permian age (Bharadwaj 1971; Tiwari 1991; Tiwari and Tripathi 1988, 1992; Banerjee and D’Rozario 1990; Kulshrestha 1990; Vijaya and Tiwari 1992; Haid and Banerjee 1994). In addition, it is commonly seen that Scheuringipollenites dominates in the Early Barakar Stage of the middle to late Early Permian age, whereas, striate disaccates, like Faunipollenites dominance in association with non-striate disaccates, like Scheuringipollenites are recorded from the Late/Upper Barakar Stage of late Early Permian (Tiwari and Tripathi 1992; Vijaya and Tiwari 1992). The lowermost and middle parts of the Lower Barakar are also characterized by Scheuringipollenites with a significant share of radial monosaccates, zonates and apiculates (Bharadwaj 1962, 1971, 1975; Tiwari 1973, 1974a, b, 1991).

By comparing the present miospore assemblage with early records of miospores from Lower Gondwana it is revealed that dominant occurrence of striate disaccate grains namely Striatopodocarpites, Striattites, etc. in assemblage confirms the Upper Permian age of the sediments. Biostratigraphic and environmental classification of Lower Gondwana sediments of India have been proposed from time to time by various workers (Feistmantel 1880; Vredenburg 1910; Wadia 1926; Saksexa 1952, 1974; Lele 1964, 1976; Roy Choudhury et al. 1973; Shah et al. 1971; Sarbadhikari 1974; Sastry et al. 1977, 1979). The generalized environmental classification of Indian Lower Gondwana (Shah et al. 1971; Lele 1976) is given in Table 1. The present miospore assemblage recovered from the Upper Permian sediments of Sonepur-Bazari Open Cast mine and their distribution pattern suggested a warm, temperate climate during the deposition of sediments. This study needs to be further extension to ascertain the comprehensive knowledge of Glossopteris flora in Raniganj Formation of Sonepur-Bazari Open Cast mine area.

Table 1. Environmental phases in Indian Lower Gondwana (after Lele 1976)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Series</th>
<th>Formation</th>
<th>Environment</th>
<th>Palaeoclimatic Floral Phase</th>
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<tr>
<td>Lower Gondwana</td>
<td>Damuda Series</td>
<td>Raniganj</td>
<td>Warm</td>
<td>Glossopteris</td>
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<td>Barren Measure</td>
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<td>Talchir Series</td>
<td>Karharbari</td>
<td>Cool</td>
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<td>Boulder beds</td>
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