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Palynology and Depositional Facet of Lower Permian (Artinskian) Sediments from New Majri Opencast Mine, Wardha Basin, India

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Abstract: Coal samples and the associated sediments from New Majri open cast mine have been analysed palynologically with the following objectives: to date the sediments on the basis of the palyno-assemblage recognised; to carry out an inter-basinal, intra-basinal and Gondwana wide correlation; to interpret the palaeoenvironment and depositional facet of the coal field on the basis of dispersed organic matter analysis and sedimentary facies analysis.

Based on the qualitative and quantitative analysis of the spore and pollen content one palyno-assemblage-*Scheuringipollenites* and *Faunipollenites* has been recognised which is typical of lower Barakar Formation. This has been correlated with known palyno-assemblages from Wardha basin and other basins in India, while with the Gondwana continents the assemblage has been broadly correlated with early Permian Australian, African, South America palynofloras as well as early Permian palynoflora of Antarctica. Consequently, a tentative late Early Permian, Artinskian age is proposed for the sediments from New Majri open cast mine. Palynological studies also revealed that the peat forming vegetation was mainly composed of gymnosperms represented by glossopterids (*Scheuringipollenites, Ibisporites, Platysaccus, Cuneatisporites*, *Primuspollenites* and *Sahnites)*, conifers (*Faunipollenites, Striatites, Striatopodocarpites*, *Verticipollenites, Distriatites*) and cordaites (*Parasaccites*, *Plicatipollenites, Crucisaccites, Divarisaccus, Densipollenites)*. Spores were represented mainly by filicopsids (*Horriditriletes, Brevitriletes, Callumispora)* and sphenopsids (*Latosporites*). The relative abundance of structured organic matter implies the existence of a fairly dense cover of vegetation in the hinterland. Anaerobic, reducing, water logged peat-forming conditions have been inferred by the presence of biodegraded organic matter and amorphous organic matter. The charcoal fragments recovered from the present study area reflects a possible wildfire in the accumulated swamps or a wildfire in the hinterland after which the sediments were flushed by fluvial systems into the swamps. The coalfield exhibits horizontal bedding pattern which may be due to deposition by suspension settling or horizontal accretion. Further the alternating high and low energy regime is noticed in the sandstone-shale intercalated beds overlying the coarse grained yellow sandstone which forms the roof of the coal seam. Comprehensively the sediments are deposited as overbank / levee deposits.

Keywords: New Majri open cast mine, Palynology, lower Barakar, Artinskian, Biostratigraphic correlation, Depositional facies.

INTRODUCTION

Through the decades extensive palynological work has been carried out in various coalfields of the Godavari basin as is evident through the contributions of Srivastava and Jha (1992a,b , 1995 a,b), Jha (2006), Jha et al. (2011a,b), Jha and Aggarwal (2010a,b, 2011a,b). On the other hand, not much palynological data has been generated from the Wardha basin, which is the northwestern extension of the Godavari basin. Some of the contributions include, Agashe and Chitnis (1970, 1972), Bharadwaj and Anand-Prakash (1974), Jha et al. (2007), Pauline Sabina et al. (2007, 2008), Mahesh et al. (2008, 2011) and Kalkar et al. (2010). However, all these studies deal with the palynological dating of sediments, albeit a few cover coal petrological (Anand-Prakash and Khare, 1974) and palaeoenvironmental aspects (Mahesh et al 2008, Pauline Sabina et al 2010) and megafloral studies (Agashe, 1979; Tewari et al. 2004; Jha et al. 2007). The Wardha basin is a broad anticline plunging towards NNW (Hughes, 1877). Recently, Jha et al. (2011a) palynologically dated the sediments from Hindustan Lalpeth colliery, Ballarpur and Durgapur areas which lie in the eastern limb of the anticline, while the present study deals with the palynological analysis from the New Majri open cast mine which is located on the western limb of the anticline. The study is focused on biostratigraphic zonation and correlation and the interpretation of the depositional facet of the sediments in the New Majri open cast mine.

GEOLOGICAL SETTING

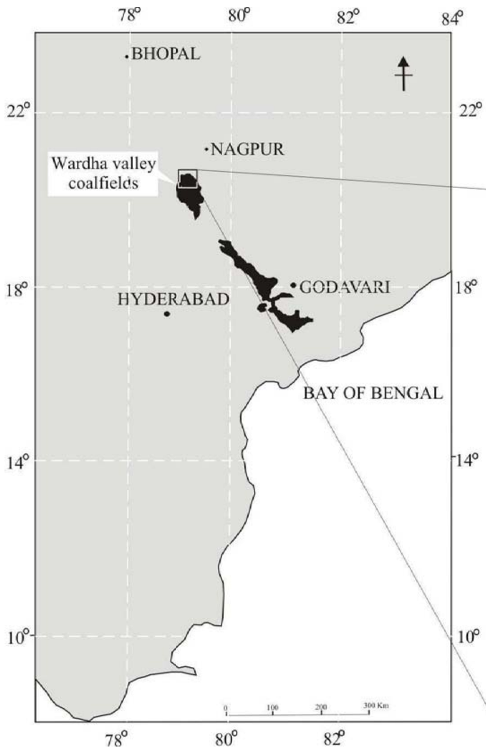
A major portion of the Wardha valley coalfield lies in the Chandrapur district of Maharashtra while a minor portion of it occurs in the Yeotmal district. It covers an area of 4,130 sq. km and extends for a length of 116 km. It lies between latitudes 19°30' and 20°27' N and longitudes 78°50' and 79°45' E. Hughes (1877) conducted the first systematic geological mapping of the entire coalfield. The coalfield is a trough bound on either side by NW-SE trending faults. The Archaean rocks are found in the eastern part while the Puranas and the Vindhyans in the west. The shales and the limestones of the Pakhal Series border the Gondwana tract with a few patches of Sullavai sandstones. The Gondwana sediments are overlain by thick alluvium and trap. Beneath the trap lies the Lameta Formation comprising of sandstones, marls and limestones. The Kamthi Formation almost covers the Barakar sediments as the coalfield had witnessed widespread denudation of the Gondwana sediments after the deposition of the Barakar Formation (Raja Rao, 1982). The Gondwana rocks are folded into a large anticline, on the eastern limb of which the occurrence of coal has been established from Sasti to Ballarpur in the south to Chandrapur, Durgapur, Bhandak and Warora in the north. While, in the western limb the occurrence of coal has been validated from Ghugus to Majri for a distance of 25 km.

New Majri Open Cast Mine

The New Majri open cast mine is located in the north western part of the Wardha valley coalfield and is bound by latitudes 20°5'10" N and 20°7'17" N and longitudes 79° 01'26" E and 79°02'29" E (Fig.1). It is a composite seam with a thickness of 17 m. The upper portion ranges in thickness from 2 m-4 m and is found to be of inferior grade, while, the lower part is the workable section. The workable section of the upper part ranges in thickness from 3.1m - 8.5 m with an intercalation of one dirt band of 0.5 m. It is separated from the lower part by a parting of 1.3 - 4.3 m. The workable section of the lower part varies in thickness from 3.5 m – 8 m. The stratigraphic sequence of New Majri Open cast mine is given in Table 1.

MATERIAL AND METHODS

The standard maceration method is implemented for the recovery of palynomorphs from the samples. Before chemical treatment the samples were cleaned and crushed. 10 grams of the crushed sample was subjected to chemical treatment. The carbonates were removed by 10% HCl and silicates by 40% HF. Further the residue was treated with Conc. HNO_3 to dissolve the organic matter and with 10% KOH to remove the humic matter. Along with this non-chemical mode like sieving and swirling was made to



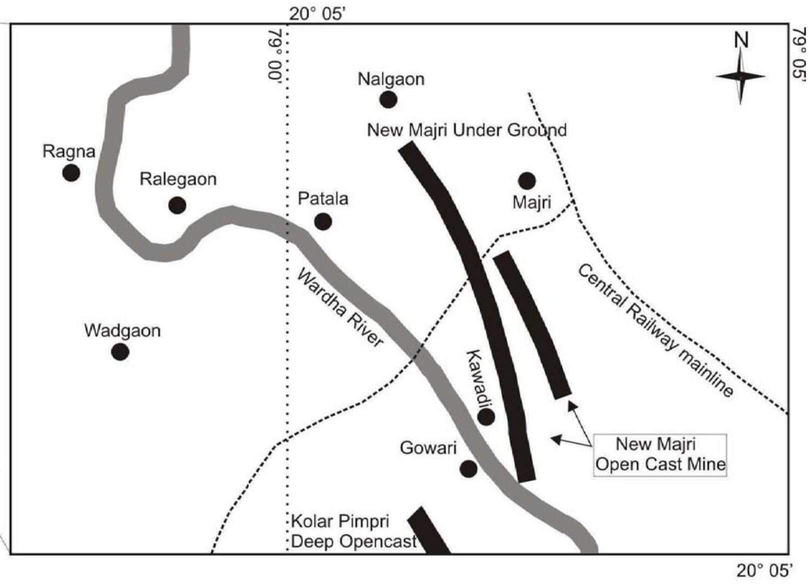


Fig.1. Location map of New Majri open cast mine.

Table 1. General stratigraphic sequence of the study area (*after* Jhanwar et al., 2006)

Formation	Lithology	Maximum Thickness (m)
Detrital Mantle	Black cotton soil, sandy soil etc.	32.05
Kamthi	Sandstone, shale and clay	86.00
Unconformity		
Barakar	Sandstone, shale, carbonaceous shale and coal seam	105.00
Talchir	Greenish grey shale and sandstone	Not ascertained

enhance the concentration of palynomorphs. The obtained macerates were mounted in canada balsam and slides were prepared for observation. Five slides were prepared from each residue and were examined under microscope. The relative percentages of the spores and pollen were based on counting 200 spores and pollen per slide.

The preparation technique employed for palynofacies studies was the standard non-oxidative palynological procedure (Faegri and Iverson, 1989). Palynofacies analysis was carried out to evaluate the content of particulate organic matter. The palynofacies technique involved the qualitative and quantitative assessment of the total organic matter comprising of the identification of all particulate organic matter constituents. The relative percentages of these components are based on counting 200 particles per slide. The kerogen classification used in this study was that of Batten (1996). Assignments of dispersed spores and pollen grains to their respective parent plant groups were based on the compilations of Balme (1995).

The sample material is housed at the Palynology Laboratory, Department of Geology, University of Mysore, India, under sample codes NMOC/R-69 to NMOC/R-76**.**

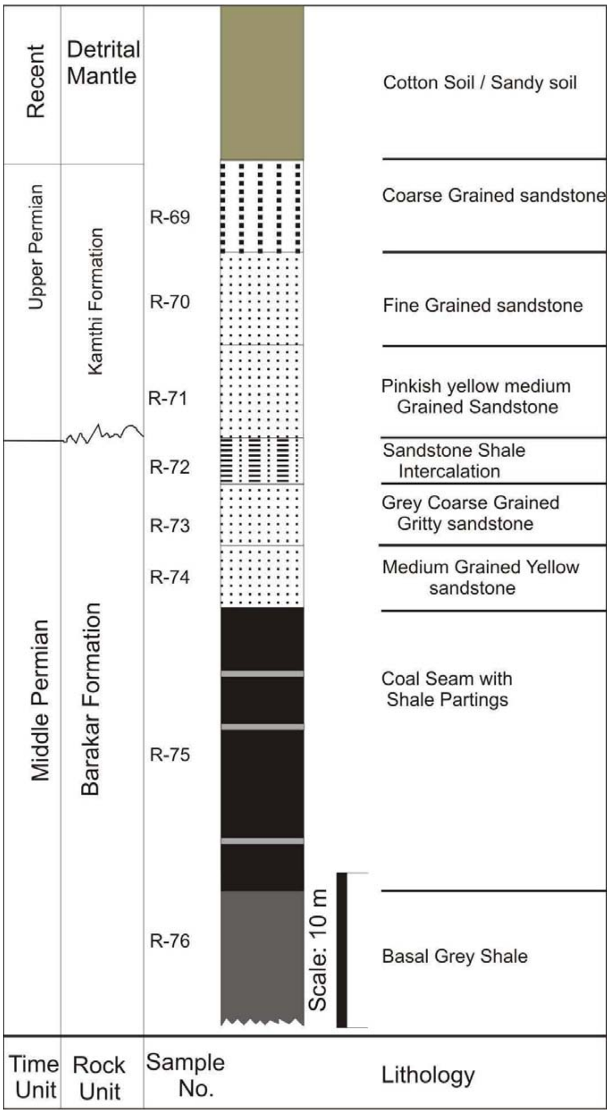


Fig.2. Lithocolumn of New Majri open cast mine, Wardha valley, Maharashtra, India.

PALYNOLOGY

A total of 15 samples were collected from the New Majri open cast mine (Fig.2). The palynomorph content indicates a strong lithofacies influence, where the sandstone facies yielded the poorest in comparison to the shale facies and coal of Barakar Formation. Therefore, the sandstone facies were analysed to interpret the depositional facet of the coalfield. The pinkish and yellowish coarse grained sandstone probably represents the Kamthi Formation and were devoid of palynomorphs. Below the sandstone facies is the shale and coal of the Barakar Formation. These samples yielded phytoclasts i.e. tracheids, cuticles, grey and black amorphous organic matter in association with palynomorphs. A detailed assessment of the palynomorph content from the productive samples i.e. both quantitative and qualitative analysis enabled the recognition of one assemblage which is illustrated in Table 2. Stratigraphically significant taxa are illustrated in Plate 1.

Assemblage I

The assemblage is recognised between 56 m to 67 m and is characterized by the dominance of the nonstriate disaccate genus *Scheuringipollenites* (26-31%) and sub-dominance of the striate disaccate genus *Faunipollenites* (20-25%). The other associated taxa include *Ibisporites* (3-4%), *Platysaccus* (2.5-5%), *Striatites* (3-5.5%), *Striatopodocarpites* (3.5-6.5%), *Verticipollenites* (1-2%),

Table 2. Palynocomposition of the productive samples from New Majri open cast mine

Area	Lithology/ Sample No	Quantitatively important taxa	Qualitatively important taxa	Other taxa	Remarks (Age)
New Majri	R.69- Cgd sst	Unproductvive			Kamthi Formation
	R.70-Fgd sst	Unproductive			
	R.71-Pinkish yellow mgd sst	Unproductive			
	R.72-sst sh Icl	Countable numbers of *Scheuringipollenites, Faunipollenites, Parasaccites*			PALYNO-ASSEMB-LAGE I Lower Barakar Formation (Early Permian)
	R.73-Grey cgd gritty sst	Unproductive			
	R.74-mgd yellow sst	Unproductive			
	R.75- Coal seam with shale partings	*Scheuringipollenites* (31%), *Faunipollenites* (25%)	*Ibisporites* (3-4%), *Platysaccus* (2.5-5%), *Striatites* (3-5.5%), *Striatopodocarpites* (3.5-6.5%), *Verticipollenites* (1-2%), *Distriatites* (0.5-1%), *Sahnites* (0.5-1%), *Cuneatisporites* (2.5-4.5%) *Primuspollenites* (1.5-3.5%) *Parasaccites* (2.5-3%), *Plicatipollenites* (1-2%), *Densipollenites* (0-1.5%), *Weylandites* (1.5-2.7%), *Tiwariasporis* (0.5-1%)	*Callumispora* (2.5-3.5%), *Brevitriletes* (2-2.5%), *Latosporites* (1-2.4%) and *Lophotriletes* (0-1%), *Crucisaccites* (0.3-1.5%), *Divarisaccus* ((0.5-1%),	
	R.76-Shale	*Scheuringipollenites* (26%), *Faunipollenites* (20%)			

Distriatites (0.5-1%), *Sahnites* (0.5-1%), *Cuneatisporites* (2.5-4.5%) and *Primuspollenites* (1.5-3.5%), Monosaccates include *Parasaccites* (2.5- 3%), *Plicatipollenites* (1-2%), *Crucisaccites* (1.5-0.3%), *Divarisaccus* (1-0.5%), *Densipollenites* (0-1.5%). Trilete spores of the genera *Callumispora* (2.5-3.5%), *Brevitriletes* (2-2.5%), *Latosporites* (1-2.4%) and *Lophotriletes* (0-1%) are also present. Besides these, *Weylandites* (1.5-2.7%), *Tiwariasporis* (0.5-1%) have also been recorded (Fig.3).

AGE AND CORRELATION

The *Scheuringipollenites+Faunipollenites* assemblage is typical palynoflora of Barakar Formation (Jha 2006) and corresponds with the *Scheuringipollenites barakarensis* zone of Tiwari and Tripathi (1992). The recorded assemblage and the majority of the associated taxa indicate a late early Permian age, Artinskian to the sediments from New Majri open cast mine.

Late early Permian assemblages have been recorded in various Gondwana basins of India. An intra-basinal correlation within the Wardha basin shows that the palyno-assemblage from the New Majri open cast mine can be correlated with the Palynoassemblage–II of Kawadi/ Majri area, Ballarpur open cast mine and Durgapur open cast mine (Jha et al. 2011a), of Gokul block, Bandar coalfield (Pauline Sabina et al. 2007), assemblage zone A of MGE-15, Wardha valley coal field (Mahesh et al. 2008) and assemblage B of Wardha valley coalfield (Bhattacharyya, 1997).

In the adjacent Godavari basin, the *Scheuringipollenites + Faunipollenites* palynoassemblage from the New Majri open cast mine can be well correlated with the Palyno-assemblage of Manuguru (Srivastava and Jha, 1992b), Palynozone 4 of Ramakrishnapuram (Srivastava and Jha, 1992a), Palynozone 5 of Budharam (Srivastava and Jha , 1995b) Palynozone 2 of Koyagudem (Srivastava and Jha, 1995a), Palyno-assemblage III of Mamakannu (Jha and Aggarwal, 2010b), Palyno-assemblage 2 of Gundala (Jha and Aggarwal, 2010a, 2011a), Palyno-aasemblage I of Kachinapalli (Jha et al., 2011b) and Palyno-assemblage I of Satrajpalli (Jha and Aggarwal, 2011b)

A regional correlation with other Gondwana basins in India shows that the palyno-assemblage from the New Majri open cast mine corresponds well with the assemblage from Giridih coalfield (Srivastava, 1973), zone 3 of Umaria coalfield (Srivastava and Anand-Prakash, 1984), zone 3 of Johilla coalfield (Anand-Prakash and Srivastava, 1984), assemblage–II of Pathakhera coalfield (Sarate, 1986), assemblage II of Talcher coalfield (Tripathi, 1993),

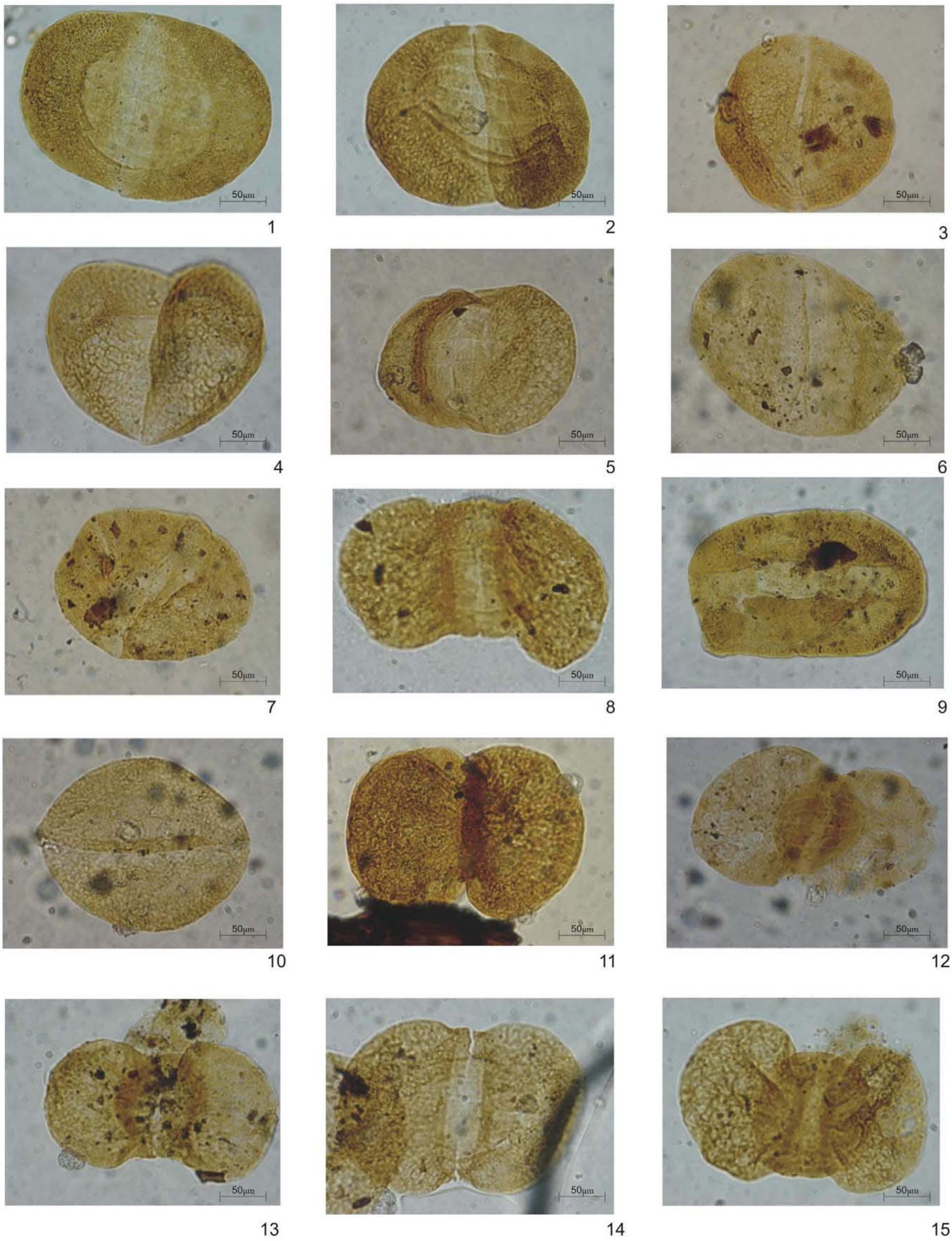


Plate 1. **(1)** *Faunipollenites magnus*, Bose and Kar (1966). **(2)** *Faunipollenites congoensis*, Bharadwaj and Salujha (1965). **(3)** *Scheuringipollenites barakarensis*, Tiwari (1973). **(4)** *Scheuringipollenites tentulus*. **(5)** *Distriatites indicus*, Sinha (1972). **(6,7,10)** *Scheuringipollenites* sp. **(8)** *Lahirites levicorpus*, Tiwari (1968). **(9)** *Divarisaccus lelei*, Venkatachala and Kar (1966). **(11)** *Ibisporites diplosaccus*, Tiwari (1968). **(12)** *Stiratites rhombicus*, Bharadwaj and Salujha (1964). **(13)** *Verticipollenites gibbosus,* Bharadwaj (1962). **(14)** *Striatites communis*, Bharadwaj and Salujha (1964). **(15)** *Platysaccus brevizonatus*, Tiwari (1968).

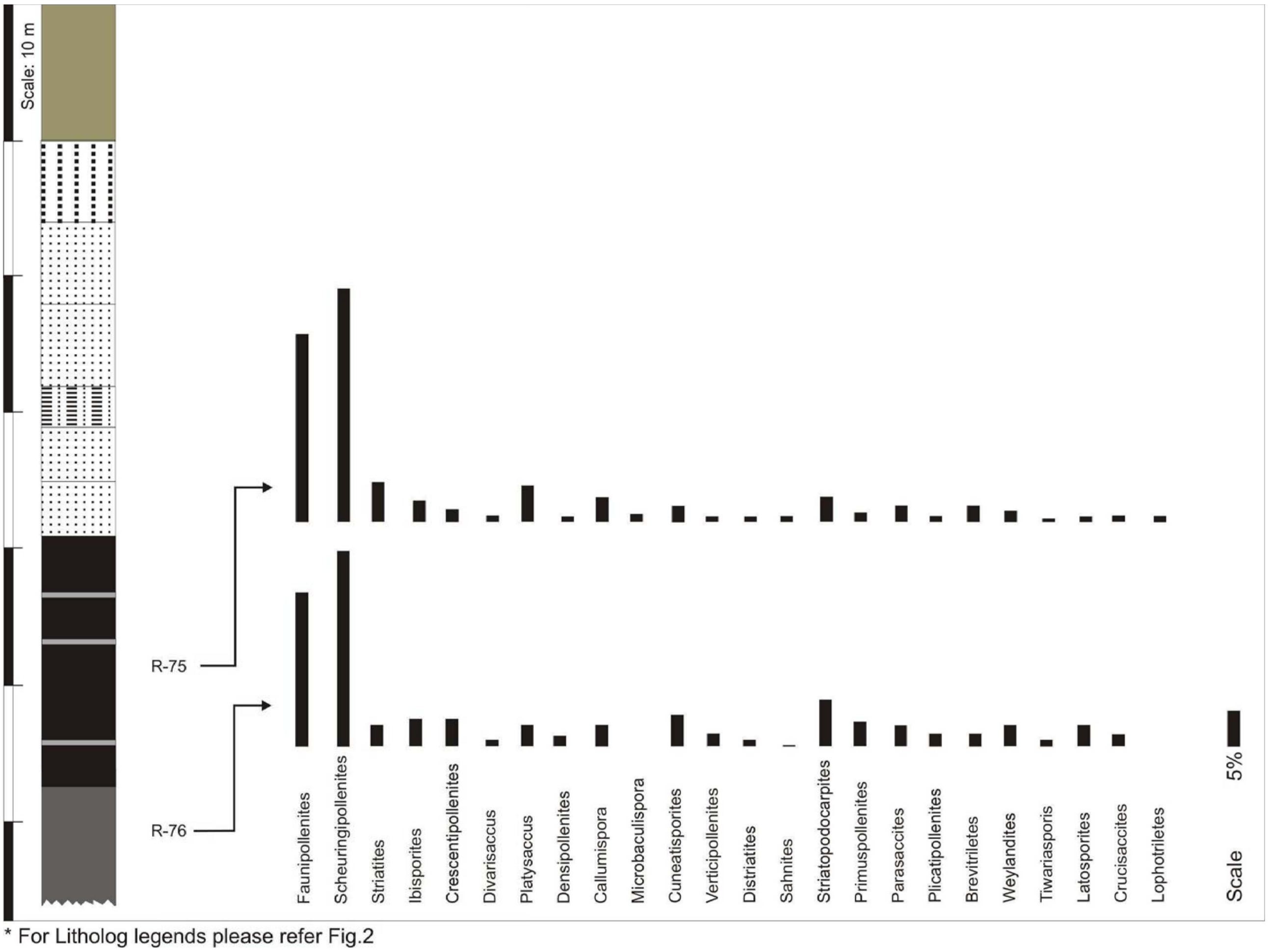


Fig.3. Histogram showing the percentage frequency of palynomorphs in the productive samples.

assemblage II from Tamra block, Raniganj coalfield (Srikantamurty et al., 2010).

Due to phyto-geographic provincialism and differences in ranges of taxa throughout the Gondwana, correlation with international stratigraphic stages is hampered (Stephenson, 2008). However a broad tentative correlation mainly based on general features of the assemblage has been made with some of the Gondwana continents. The *Scheuringipollenites* + *Faunipollenites* palyno-assemblage from the New Majri open cast mine can be tentatively correlated with Stage V of Kemp et al. (1977) of Australia due to the preponderance of non-taneiate bisaccate genus *Scheuringipollenites* spp. and presence of *Faunipollenites* spp., although there is some disparity in occurrence data between these assemblages. A comparison of the assemblage from New Majri open cast mine with those described by Lindstrom (1995) from Heimefrontfjella mountain range, Antarctica reveals that the upper part of locality A broadly correlates with the present assemblage. The most characteristic taxa pertinent to this correlation include species of *Scheuringipollenites, Faunipollenites, Striatopodocarpites, Weylandites and Laevigatosporites.* It closely corresponds to biozones KK 2 and KK 3 of STRAT I of Karoo basin, South Africa (Modie Benson and Le Herisse, 2009) on the basis of occurrence of palynotaxa such as *Scheuringipollenites* spp., *Faunipollenites* spp. *Weylandites* spp and *Laevigatosporites* sp. The biozones KK 2 and KK 3 of STRAT I of Karoo basin, Botswana was correlated with *Scheuringipollenites barakarensis* zone of Tiwari and Tripathi (1992). The present assemblage may be tentatively correlated with the *Lueckisporites virkkae* interval zone of Souza and Marques-Toigo (2003, 2005) and Souza (2006) of Paraná basin, South America. Taxa favouring their correlation are species *Striatopodocarpites*, *Faunipollenites*, *Weylandites* although *Marsupipollenites* spp has not been recorded in the former assemblage.

DEPOSITIONAL ENVIRONMENT

Palaeobotanical Inferences

Palynological analyses demonstrated well preserved palynomorphs showing dominance of bisaccate pollen grains related to gymnospermic vegetation of which non-striate bisaccates are the most important group in the palyno-assemblage, accounting for 48.9% of the palynomorph population. They are represented by *Scheuringipollenites, Ibisporites, Platysaccus, Cuneatisporites*, *Primuspollenites* and *Sahnites* pointing out the significance of Glossopterids in the peat forming vegetation. Striate bisaccates constitute 27.14% of the total palynomorph population represented by *Faunipollenites, Striatites* , *Striatopodocarpites* , *Verticipollenites, Distriatites* reflecting the presence of conifers in the peat forming vegetation. Monosaccate pollen grains constitute 9% of the palynomorph population and are represented by *Parasaccites*, *Plicatipollenites, Crucisaccites, Divarisaccus, Densipollenites* indicating presence of cordaites also in the peat forming flora. Spores constitute 9.5% of the palynomorph assemblage represented by filicopsids (*Horriditriletes, Brevitriletes, Callumispora*) and sphenopsids (*Latosporites*).

This diversified flora likely reflects the initiation and prevalence of warm trend in the late early Permian unlike the impoverished and less diversified flora of the Talchir Formation of early early Permian. The Cisuralian palynofloras of Gondwana are characterized by new groups of lycophytes, pteridophytes and sphenophytes together with an abundance of gymnosperms (Cesari and Gutierrez 2001). Some of these plant groups are more typical of warmer palaeoenvironments linked with the Gondwana movement towards lower latitudes (Mcloughlin 2001). This indicates that a warm climate had pervaded during the late early Permian period which favoured luxuriant growth of vegetation which under favourable geological conditions resulted in the formation of coal. The dominance of sub-arborescent /arborescent vegetation suggests a development in a forest swamp probably in a small distant marginal part of the mire or periods of stagnant water. This flooding environment favoured the growth of herbaceous lycopsids, filicopsids and sphenopsids in the palaeomire (DiMichele and Philips1994). The high representation of glossopterids, conifers and cordaites co-occurring with filicopsids, lycopsids and sphenopsids are indicative of a hypautocthonous taphocenose (Birks and Birks 1980). Scarce sphenopsids (*Latosporites*) are also recorded, an ancient plant community which has been interpreted as swamp-margin colonist flourishing on flooded swamp or surrounding areas (Pryor, 1996).

Palynofacies

The total organic matter is constituted by the dominance of palynomorphs which accounts for 60% of the total organic matter, followed by opaque phytoclasts (19.37%), structured organic matter (15%), biodegraded organic matter (2.40%) and amorphous organic matter (AOM) (3.73%).

The relative abundance of structured organic matter implies the existence of a fairly dense vegetation cover in the hinterland. It also indicates anaerobic, reducing, water logged peat-forming conditions (Diessel and Smyth, 1995). Reducing, anaerobic conditions can also be inferred by the presence of amorphous organic matter. The AOM is mainly a spongy and membranous that dominates the association probably derived from vascular land plants suggesting a non-marine provenance (Batten, 1983). Another evidence that organic matter inputs are of terrestrial origin is that both the structured and biodegraded organic matter consists exclusively of higher plant debris at different stages of diagenetic alteration, as is evident by their partly preserved original structures implying the organic matter inputs were dominanatly from terrestrial materials. The opaque phytoclasts are typical charcoal as it is black, opaque, brittle and angular with an elongate prismatic appearance displaying some cellular structure (Enache and Cumming, 2006). The organic fragments that are regularly perforated with bordered pits and partly split into woody splinters are commonly identified as charcoal fragments (Batten 1973, 1981). The opaque phytoclasts are chiefly of the blade shaped type, reflecting deposition in proximal environments (Batten and Stead, 2002). They also imply oxidizing conditions in exposed areas of flood plains and river beds. According to Batten and Stead (2002) in fresh water and brackish environments, oxidizing and high or low energy conditions may be associated with periodically exposed areas of floodplains and riverbeds, and lakes or lagoon margins. Periodic oxidizing environment may have also resulted due to a retarded subsidence (Tavener- Smith et al. 1988) which caused the peat to desiccate and thus leading to partial saturation of peat rendering it liable to combustion. Alternatively, fire formed inertinite could have been aqueously transported into the peat forming environment (Nichols and Jones. 1992) while very small pieces may have been blown in. The charcoal fragments recovered from the present study area reflects a possible wildfire in the accumulated swamps (Cope, 1981; Chaloner, 1989) or a wildfire in the hinterland after which the sediments were flushed by the fluvial systems into the swamps. Sedimentary charcoal is widely accepted to be the product of pyrolysis of mainly land plant matter during wild fires (Batten, 1975; Chaloner and Cope 1982; Scott and Jones, 1994).

Depositional Facies

The field study of the relationship of the coal seam with respect to its allied lithology gives us an idea about the nature of deposition in the present study area. The horizontal bedding seen in the coalfield may be developed in different types of environments such as sediment suspension, horizontal accretion, encroachment of the lee of an obstacle etc (Prothero and Schwab, 1996). The palynological study of coal bed and field observation of the associated lithologies has enabled us to frame the following depositional facies (DF) for a broader understanding of the depositional milieu of this particular coalfield (Table 3).

Table 3. Depositional facies of sediments in New Majri open cast mine

Depositional Facies	Lithology	Thickness (m)
DF-I	Sandstone (medium to fine grained, pinkish yellow, grey sandstone)	27
DF-II	Sandstone-shale intercalation	3
DF-III	Yellow coarse grained sandstone (roof of coal seam)	1.5-2
DF-IV	Coal	17

DF-I (Medium-fine grained sandstone)

Pinkish yellow and grey medium grained sandstone with an over all thickness of 15 m overlies the fine grained sandstone. These sediments were deposited by the breach in the river bank deposit (levee) which flowed into the plain carrying coarser bed load particles with it. Due to its high energy regime the underlying sediments from the sandstone shale intercalation are scoured along the channel pathway and is evident by the lenticular beds of sandstone. The contact between sandstone shale intercalated bed and medium grained sandstone bed is erosional which is evident by the thinning away of sandstone shale Intercalated bed into medium grained sandstone (Fig.4A).

Three sandstone beds of approximately 7 m, 2 m and 3 m thickness are deposited horizontally with sharp but characteristically non-erosive contacts. These sediments were deposited by the overbank flow process which grade into medium to fine grained sediments away from the channel margin.

DF-II (Sandstone Shale intercalation)

2-3 m thick fine grained sandstone with shale succeeds the underlying yellow coarse grained sandstone. Sandstone was deposited in a medium-high energy environment as bed load particles before the cessation of flood water inflow into the adjacent plains from the river. The intercalation of sandstone and shale is due to the alternating sedimentation of bed load and suspended particles under periodic low and very low energy (Holland et al., 1989). The shale intercalation indicates the deacceleration of sediment inflow and suspended particle deposit due to low energy (Fig.4B). These deposits form a sheet of approximately 0.5 m thick in the area with varying horizontal thickness.

DF-III (Yellow coarse grained sandstone)

At the roof of the coal bed, yellow coarse grained sandstone with a thickness of 2 m, has a sharp contact with

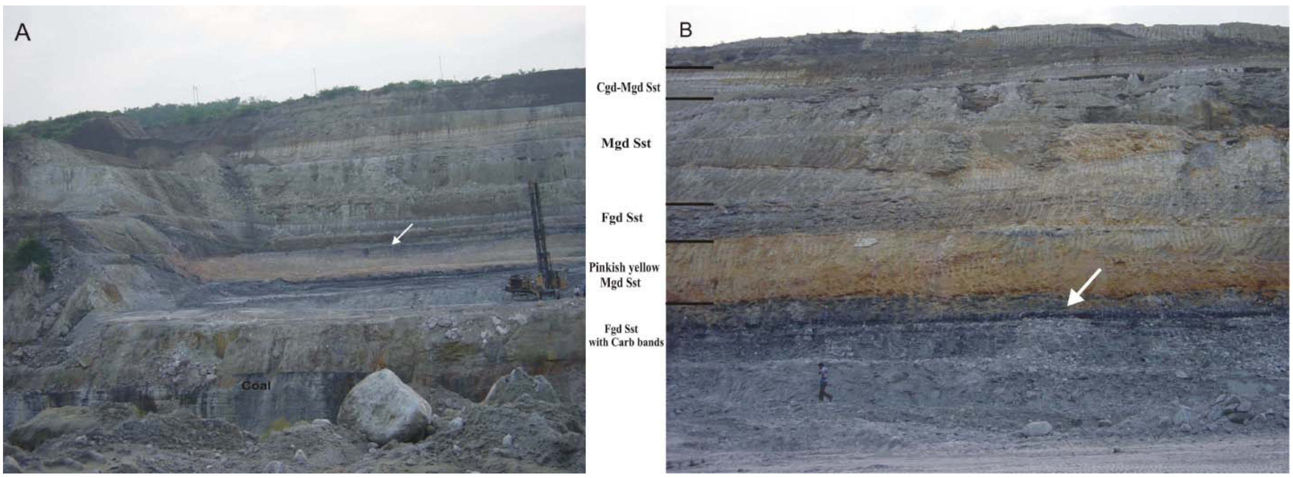


Fig.4. (A) The thinning of the contact of underlying pinkish yellow sandstone into the overlying medium grained sandstone with carb bands indicating an Erosional feature. **(B)** The rate of sediments influx into the subsiding swamp was reduced for a short period and this allowed the deposition of organic matter which formed the carb bands. This is due to the withdrawal of the distributary channels.(Mark Taylor, 1981)

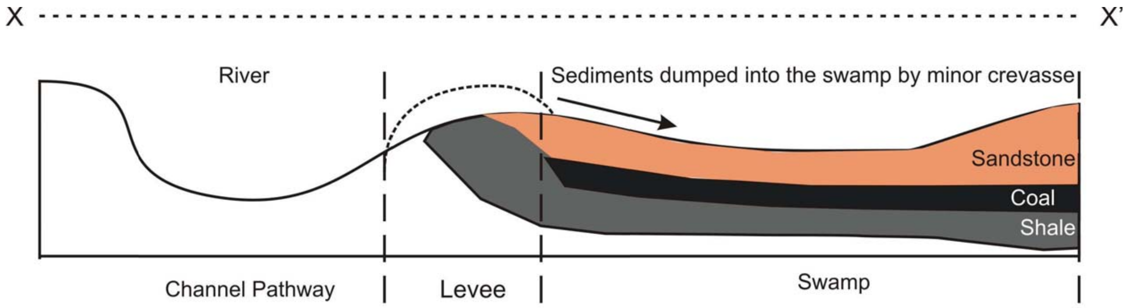


Fig.5. Reconstruction of levee deposit and its transport through minor crevasse channels and deposition of sediments over the peat in a continuous sinking swamp.

the underlying coal which is indicative of abrupt termination of organic debris by incursion of sediments and erosion followed by deposition. Moderate to poor sorting of the sediments and massive nature of the beds indicate rapid dumping of the sediments over a slope (Cairncross, 1986). After the deposition of peat there was a high energy milieu in which the coarser sediments scoured the surface of peat bed while being deposited resulting in sharp contact with the coal bed. The possibility of a significant amount of peat being eroded and deposited in adjacent areas cannot be ruled out in the study area. 4m thick coarse grained gritty sandstone is deposited above the yellow sandstone. This deposit was due to the horizontal accretion of sediments as they were not transported further because of their coarse grained nature. This sort of deposits is formed by sand travelling as sheets along the bed.

DF-IV (Coal Seam)

The accumulation of organic matter in a water logged or marshy swamp that is not prone to large amount of sediment influx gives rise to coal seams (Dutcher, 1980; Falcon, 1986). In the present study it is evident that the area was below the water level and subsiding rapidly which facilitated the influx of organic matter forming the peat bogs. The swamps were inundated with flood water and the subsidence of the area resulted in cutting off of the fresh water flow into the swamps there by depriving the oxygen content resulting in rapid transformation into anaerobic and acidic conditions of the swamps with good preservation of organic matter resulting in coal formation (Falcon 1986; Cadle et al., 1993). The coarse to medium grained nature of the sediments indicate that the beds may have been formed due to horizontal accretion and as overbank deposit. The parting in between the seam is a sign of interlude in peat deposition due to the increased sediment influx vis-à-vis organic matter.

On the whole the adjacent plains and back swamps were fed by the flood waters of the meandering Wardha river. The present study area is juxtaposed to the river channel which deposited the sediments in the form of levees and then breached by crevasse (Fig.5). The area was a gradual sinking swamp. Slicken-slides seen in the present area are mainly due to uneven compaction of the beds.

CONCLUSIONS

Although palynological studies have been carried out in the New Majri open cast mine, this is perhaps the first detailed account covering aspects of both biostratigraphic correlation with reference to other Gondwana continents and interpretation of depositional environment of the coalfield. Palynological analysis carried out revealed that the palyno-composition is characterized by the dominance of *Scheuringipollenites* and sub-dominance of *Faunipollenites* which is typical lower Barakar palynoflora of late early Permian affinity. Correlations with other coalfields of Wardha basin and other Gondwana basins in India have been established. Owing to limiting factors such as phytogeographic provincialism and ranges of taxa only broad, tentative correlation with Gondwana continent has been established. The assemblage shows a broad correlation with stage V of Australia (Kemp et al. 1977) and *Lueckisporites virkkae* interval zone (Souza, 2006) of Paraná basin, South America. Shrimp U-Pb dating of the Irati Formation in the Paraná basin revealed an age of 278.4 Ma (Artinskian) for the middle portion of the *Lueckisporites virkkae* interval zone (Santos et al. 2006). Consequently, a late early Permian age, Artinskian is proposed for the sediments from the New Majri open cast mine. Palynological studies also revealed that the peat forming vegetation mainly composed of gymnosperms represented by glossopterids, conifers and cordaites. Spores were represented mainly by filicopsids and sphenopsids. Palynofacies analysis reveals that the organic matter inputs were from terrestrial materials and a fairly dense vegetation cover existed in the hinterland. The occurrence of charcoal in sediments broadly confirms palaeo-wildfire. So a palaeo-wildfire episode can be deduced from the study area as large number of charcoal fragments are found in the sandstone strata lying above the coal seam. The almost intact nature of the charcoal fragments signifies that they were transported for a shorter distance and hence probably of parautochthonous deposition. Proximal environments have also been deduced on the basis of the predominance of blade shaped opaque phytoclasts over the equidimensional ones.

In general the sediment deposition was initially by flood basin followed by levee deposits and then the minor crevasse deposit breaching the levee. The levee breaches are clearly evident in the north western part of the coalfield on the left bank of river Wardha. Many drainages along the major river path fed the surrounding swamps with water and debris, keeping them water logged which facilitated peat formation.

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