Permo-Triassic palynofossils and depositional environment in Satpura Basin, Madhya Pradesh*

Pramod Kumar

Birbal Sahni Institute of Palaeobotany 53-University Road, Lucknow-226007, India

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Permo-Triassic deposits known as Bijori and Pachmarhi Formations in Satpura basin are well exposed in the Tamia scarp at Tamia in Chhindwara district, M.P. The argillaceous facies of Bijoris are unconformably overlain by the arenaceous Pachmarhi Sandstones.

The carbonaceous shales of Bijoris contain rich striated - disaccates e.g., *Striatopodocarpites, Faunipollenites* with *Densipollenites* and *Crescentipollenites* and a few taeniate forms *Corisaccites, Guttulapollenites, Lunatisporites*, etc. (Palynoassemblage-A), whereas the khaki-olive (buff coloured) clay bands of Pachmarhis possess rich non-striated disaccates: *Falcisporites, Satsangisaccites* with *Nidipollenites, Alisporites, Klausipollenites, Chordasporites*, etc., as well as polysaccate-*Goubinispora, Trochosporites* and appearance of cingulizonate forms *Playfordiaspora, Lundbladispora* (Palynoassemblage-B). The presence of *Staurosaccites* and *Brachysaccus* is a noteworthy feature of the assemblage. *Palynoassemblage - A* of Bijoris at Tamia Ghat Road is comparable with the Late Permian palynoassemblages of Damodar (Raniganj Fm.), Son (Nidpur beds), Godavari (Kamthis), Satpura (Sukh-Tawa section) and Nagpur (Kamthis - Palynozones - 1 & 2). *Palynoassemblage - B* of Pachmarhis in the same section of Tamia closely compares with the Early Triasic (Scythian) palynoassemblages of Son (Nidpur beds), Rajmahal (Palynoassemblage-A of Dubrajpur Fm), Damodar (Panchet Fm), Kamthi coalfield (Palynozone-3).

Sediments (argillaceous) of Bijori Formation exposed at Tamia indicate a Permo-Triassic influence having a warm humid climate, deposited under swampy conditions with gradual drying up of the basin. The arenaceous Pachmarhi Formation was deposited as a huge sand bank having warm, semi-arid climate and prolonged seasonal droughts.

Key-words- Palynostratigraphy, Permian-Triassic, Bijori-Pachmarhi Formations, Paleoenvironment, Satpura basin.

INTRODUCTION

PERMO-TRIASSIC sediments, described as Bijori and Pachmarhi formations, are exposed to the south of the Pachmarhi plateau in Satpura basin, Madhya Pradesh. The argillaceous facies of Bijoris are unconformably overlain by the arenaceous Pachmarhi Sandstones with lenses of variegated clays which are mostly developed in the eastern part of the basin.

Megafloral records from Bijoris are very poor. Medlicott (1873), Feistmantel (1879), Crookshank (1936) and Sastry *et al.* (1977) reported plant fossils as *Schizoneura gondwanensis* (Equisetales); *Sphenophyllum (Trizygia) speciosum* (Sphenophyllales); *Sphenopteris (Dicksonia* sp), *Cladophlebis roylei, C. lindleyana, Pecopteris phegopteroides* (Filicales); *Noeggerathiopsis hislopi* (Cordaitales); *Glossopteris damudica, G. retifera, G. angustifolia, G. conspicua, G. indica, G. communis, Gangamopteris cyclopteroides, G.* cf. *G. whittiana, G.* sp. (Pteridospermae); *Samaropsis* cf. *parvula, Vetebraria indica* (tree trunks), etc.

Vertebrate fossils from Bijori Formation known as *Gondwanosaurus bijoriensis* (labyrinthodont) has only been reported by Lydekker (1885). Since then no animal fossils has so far been reported from this formation.

Records on palynofossils from Permian sediments of Satpura basin are very meagre. Bharadwaj *et al.* (1978), Salujha and Kindra (1984) and Sarate and Patil (1994) described palynoflora from Bijori Formation.

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The Lower Triassic Pachmarhi Formation in Mahadeva Group contains very few plant fossils. A few branchlets and badly preserved rachis of some ferns were recorded by Crookshank (1936).

Fossil estheriids have been identified from this unit by S. Chandra (1972, in Sastry *et al.* 1977).

Reports on palynofossils from this unit in this basin are almost negligible. Recently Kumar (1995) has recorded well preserved palynomorphs from Pachmarhi Formation.

PALYNOASSEMBLAGES

Out of 14 samples analysed for the palynological studies, four samples i.e., 1,2,8 and 13 (Table-2), have yielded palynofossils. Lithofacies of yielding samples nos. 1,2 and 8 are carbonaceous in nature while 13 is clay of Khaki-olive in colour. In spite of the paucity of the spores these findings are very significant because no Permo-Triassic palynoflora is known so far from this basin and the palynodating of such rocks is an important objective of this communication.

Table-1. Geological succession in the Tamia Ghat Road, Tamia

	Age	Formation	Lithology (thickness in meter)
	Recent	Laterite	
	Eocene-Upper Cretaceous	Deccan Trap flows	
Middle Gondwana	Lower Triassic	Pachmarhi (± 750 m thick)	Thick beds of coarse white sandstones, separated by layers of white Quartz pebbles. A bed of red clays, at the base, Khaki olive clays in lenses, current bedded sandstones
		——————Unconformity——————	
Lower Gondwana	Upper Permian	Bijori (± 250 m thick)	Olive, buff coloured clays and shales with earthy sandstones and occasional carbonaceous beds, a few red clays.

The objects of the present study are to recover the palynomorphs their changing pattern, if any correlation with the other palynoassemblages as well as their impact on climatic or environmental changes during their depositions in the Satpura basin, etc.

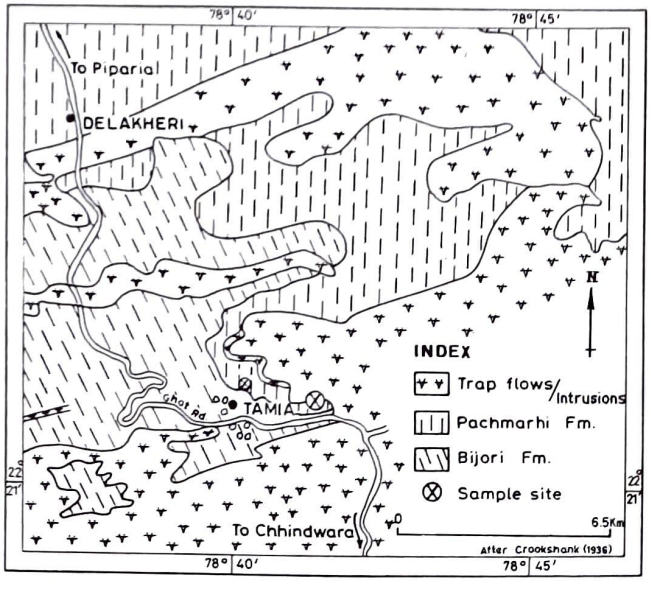
Geological setting of the area: (Map-1)

The geology of the area has already been discussed by Crookshank (1936), Singh and Ghosh (in Sastry *et al.* (1977) and Raja Rao (1983) in detail.

In short, the palynofossils yielding rocks are exposed in the Tamia cliffs. At the Tamia Ghat Road, the carbonaceous (argillaceous) facies of the Bijori Formation are exposed at the base of the cliff and cliffs of conglomeratic sandstones (arenaceous facies) of Pachmarhi Formation are found unconformably overlying the Bijoris. The buff coloured clays with carbonaceous shales completely disappear and are replaced by a white sandy conglomerate with very thin clay partings. These clays are mostly white but in one or two instances red clays with mottled red, Khaki clays are also present, which are designated as the Pachmarhi Formation (Fig. 1, Table-1).

The normal maceration technique has been employed to recover the palynomorphs.

The percentage frequency of the palynomorphs is given in Fig. 1, and used here as: *Dominant* < 20%, *Subdominant* between 20-10%, *Common* between 10-5%, *Fair* between 5-2% and *Poor* or *Rare* > 2%. On the percentage basis two palynoassemblages have been demarcated as under.



Map-1 : Showing Permo-Triassic sediments exposed at Tamia, Chhindwara district, M.P.

Palynoasemblage - A: Sample Nos. 1, 2 and 8 (Fig. 1, Table-2) contains the following percentage frequency of palynomorphs in each samples:

Dominant forms:	Sample Nos.1	2	8
Striatopodocarpites	28.00%	16.00%	30.00%
Subdominant:			
Faunipollenites	15.00	26.00	26.00
Densipollenites	10.00	02.00	10.00
Scheuringipollenites	10.00	07.00	16.00
Common			
Lunatisporites	06.00	09.00	05.00
Alisporites	06.00	10.00	04.00
Striatites	06.00	04.00	-
Klausipollenites	10.00	03.00	01.00
Fair:			
Crescentipollenites	02.00	05.00	-
Guttulapollenites	03.00	-	-
Poor or Rare:			
Corisaccites	01.00	-	-
Rhizomaspora	01.00	-	-
Striamonosaccites	02.00	-	01.00
Gondisporites	-	01.00	-
Parasaccites	01.00	-	01.00
Distriatites	01.00	-	-
Callumispora	02.00	01.00	01.00
Lophotriletes	01.00	-	-
Leiotriletes	-	01.00	-
Cyclogranisporites	-	02.00	-
Playfordiaspora, -	02.00	01.00	
Striapollenites	-	02.00	01.00
Cuneatisporites	01.00	06.00	01.00

Palynoassemblage - B: Sample No. 13 (Fig.1, Table-2) Khaki-olive clays, contains the following of palynomorphs:

Dominant forms:	Sample No. 13
Falcisporites	25.00%
Subdominant:	
Satsangisaccites	15.00
Striatopodocarpites	14.00
Common:	
Lunatisporites	05.00
Alisporites	05.00
Fair	
Klausipollenites	04.50
Podocarpidites	04.00
Faunipollenites	03.50
Scheuringipollenites	04.00
Densipollenites	04.00
Poor/Rare	
Chordasporites	01.00
Striatites	02.00
Distriatites	02.00
Guttulapollenites	02.00
Corisaccites	02.50
Palyfordiaspora	02.00
Lundbladispora	01.00
Goubinispora	02.00
Trochosporites	01.50
Callumispora	01.00
Osmundacidites	01.00
Staurosaccites	01.00
Weylandites	01.00

Palynoassemblage - A: has the dominance of *Striatopodocarpites* (± 24.00%) associated with *Faunipollenites* (± 22.00%). The other commonly known components are *Scheuringipollenites* (± 11.00%), *Densipollenites* (± 07.00%), whereas *Crescentipollenites* (02.00%), *Playfordiaspora* (01.00%), *Guttulapollenites* (01.00%) are poorly known form of the assemblage.

Palynoassemblage-B: possesses the dominance of *Falcisporites* (± 25.00%) followed by *Satsangisaccites* (± 15.00%). The other significant forms as *Klausipollenites* (04.00%), *Chordasporites* (01.00%), *Goubinispora* (02.00%) *Trochosporites* (01.00%), *Staurosaccites* (01.00%) and *Lundbladispora* (01.00%).

The salient features of the Assemblage - B are the occurrence of *Chordasporites, Playfordiaspora, Goubinispora, Trochosporites, Brachy saccus* and *Staurosaccites* which are absent in the Palynoassemblage - A.

Comparison with the other palynoassemblages

Palynoassemblage-A - from Tamia Ghat Road, Tamia compares well with the palynoassemblages described by Bharadwaj *et al.* (1978), Salujha and Kindra (1984), Sarate and Patil (1994) from Bijori Formation exposed at Sukhtawa nala in Pench-Kanhan-Tawa valley, Bijori sediments, Denwa river and Harshdwarnala sections in Satpura basin respectively, in having more or less similar dominance of *Striatopodocarpites* followed with *Faunipollenites*. The presence of *Guttulapollenites, Corisaccites, Densipollenites, Crescentipollenites* and *Playfordiaspora* is noteworthy. These elements are also recorded from the sediments deposited in the same time span in the other basins namely the Late Permian Palynoassemblage zone-III known from Budharam and

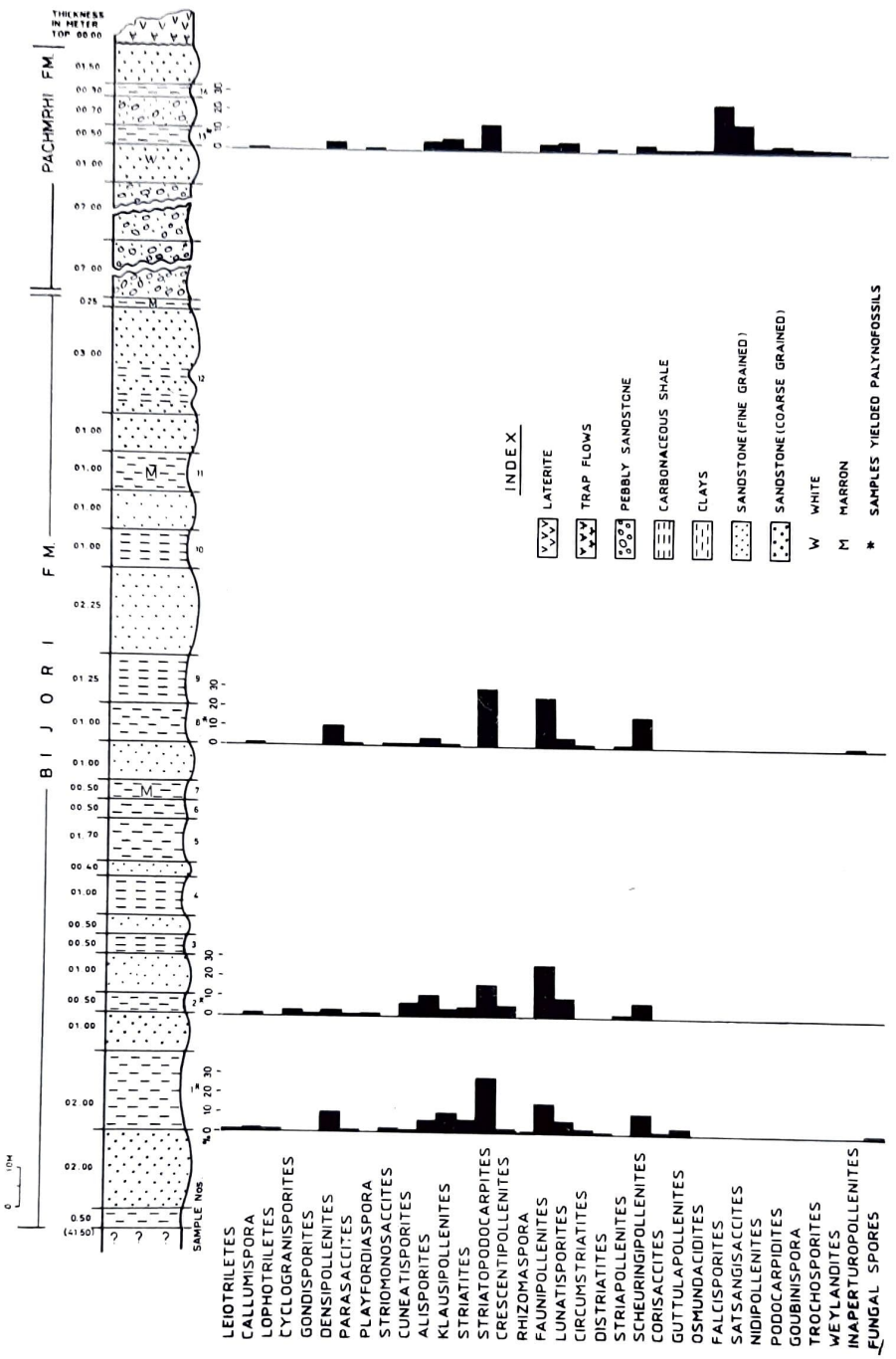


Fig. 1: Section of Permo-Triassic sediments exposed at Tamia Ghat Road, Tamia, Chhindwara District, M.P.

Mailaram areas of Godavari Graben, described by Srivastava and Jha (1988, 1990, 1995), Palynozones 1 & 2 by Srivastava and Bhattacharyya (1996) from Bazargaon, Nagpur, Upper Permian Palynoassemblage "A" of Nonia nala section of Raniganj coalfield described by Bharadwaj *et al.* (1979); palynoassemblage from Sehra nala section and Nidpur beds of Son Graben by Tiwari and Ram-Awatar (1990).

The palynoassemblage - A of Tamia Ghat Road fairly compares with the Sukhtawa palynoassemblage (Bharadwa *et al.* 1978) though it contains higher incidence of *Guttulapollenites* + *Corisaccites* (2.0 and 11.5% in two samples) complex in Sukhtawa section but it is lowly represented here (in sample No.1 as 03.00%). Its occurrence in rarity has also been reported from Upper Permian of South Africa (Hart in Goubin, 1965), India (Kar, 1970) and Triassic (?) of Australia (Balme, 1970). The spore genus *Playfordiaspora* (0.5%) is recorded from Bore hole NCRD-6 (Sample No. 13, depth 357-358.40m): included as assemblage-III at Dishergarh-Asansol

Table-2. Details of samples collected from rocks exposed at Tamia Ghat Road Section at Tamia, Chhindwara district, M.P. Productive samples are marked by an asterisk (*).

Sl.No.	Sample No.	Lithology	Thickness in meters	Palynomorphs Present (+) Absent (-)
1.	(Top)	Sandstones	01.50	-
2.	14	Clay band	00.30	-
3.	-	Sandstones	00.70	-
4.	13*	Clays (Khaki-olive)	00.50	+
5.	-	Sandstones (White coarse)	01.00	-
6.	-	Conglomeratic white sandstones, coarse gritty with small pebbles	07.00	-
7.	12	Coarse sandstones with carbonaceous thin layers	03.00	-
8.	-	Sandstones	01.00	-
9.	11	Clays (maroon coloured)	01.00	-
10.	-	Sandstones	01.00	-
11.	10	Carbonaceous shales	01.00	-
12.	-	Sandstones	02.25	-
12.	9	Carbonaceous shales	01.25	-
13.	8*	Carbonaceous shales	01.00	+
14.	-	Sandstones	01.00	-
15.	7	Clays(maroon)	00.50	-
16.	6	Clays (buff)	00.50	-
17.	5	Carbonaceous shales	01.70	-
18.	-	Sandstones	00.40	-
19.	4	Carbonaceous shales	01.00	-
20.	-	Sandstones	00.50	-
21.	3	Carbonaceous shales	00.50	-
22.	-	Sandstones (fine grained)	01.00	-
23.	2*	Carbonaceous shales	00.50	+
24.	1*	Clays (buff coloured)	02.00	+
25.	-	Sandstones	02.00	-
26.	-	Clay (buff)	01.00	-

region, Raniganj Coalfield in Damodar Basin, W. Bengal by Bharadwaj and Tiwari (1977). It becomes (5.5%) in the younger Assemblage - I in sample No. 5, depth 86 m and no. 7 at 123.5 m in Panchet Formation in the same bore hole.

Palynozones - 1 & 2 in sub-surface at Bazargaon, Nagpur described by Srivastava and Bhattacharyya (1996) are closely comparable with the Palynoassemblage-A of Tamia Ghat Road in having fair to common occurrence of *Crescentipollenites* and *Densipollenites*. But differs in lacking *Playfordiaspora*.

The Palynoassemblage-A of Tamia Ghat Road section, appears to be younger than the palynoassemblage of Sukhtawa section (Bharadwaj *et al.* 1978) and Sarate and Patil (1994) from Denwa River section in having higher incidence of *Alisporites*, *Klausipollenites*, *Lunatispoites*, *Playfordiaspora*, etc., which indicate a closer proximity towards the Permian-Triassic transition which is also supported by Tiwari and Vijaya (1992).

Palynoassemblage - B is comparable with the Lower Triassic palynoassemblages described by Bharadwaj and Srivastava (1969) from Nidpur beds and Mahadeva Formation of South Rewa Basin by Tiwari and Ram-Awatar (1990-1992); Tiwari *et al.* (1984), Tripathi *et al.* (1990) from Assemblage-A of Rajmahal Basin; Bharad-

waj and Tiwari (1977), Tiwari and Rana (1980, 1984), Tiwari and Singh (1983, 1986), Singh and Tiwari (1982), Singh (1984) from Raniganj Coalfield of Damodar basin. Srivastava and Jha (1988, 1990, 1995) from Mailaram and Budharam areas in Godavari Graben. Palynozone-3 described by Srivastava and Bhattacharyya (1996) from Bazargaon, Nagpur. Nandi (1994) and Kumar (1995) have reported palynofossils from Upper Gondwana of Satpura basin and Chota Mahadeva scarp of Tamia cliff in Satpura basin respectively.

Palynoassemblage from Zone-II (NID-8, to MB) of Nidpur beds South Rewa basin of M.P. (Bharadwaj & Srivastava 1969) and Tiwari and Ram-Awatar (1990, 1992) contains better representation of *Falcisporites, Satsangisaccites, Nidipollenites, Alisporites, Klausipollenites, Podocarpidites, Goubinispora, Weylandites* etc., where as striated and taeniate (*Striatopodocarpites, Faunipollenites*) pollen of Permian are at their low ebb. This closely compares with the Tamia palynoassemblage - B of Pachmarhi Formation (Fig.1), in having better representation of the above palynomorphs but here the palynoassociation is marked by the dominance of *Falcisporites - Satsangisaccites* followed by *Striatopodocarpites*. The present assemblage has poor pteridophytic spores which are common to other assemblages, viz., *Callumispora* and *Osmundacidites*.

Tiwari *et al.* (1984), Tripathi *et al* (1990) recorded a late Lower Triassic Palynoassemblage-A from BH-RJR-2 (depth between 840.00 and 671.05 m) of Dubrajpur Formation in Rajmahal basin, Bihar. The palynomorphs common to both the assemblages are: *Satsangiscaccites, Alisporites, Klausipollenites, Striatopodocarpites, Lundbladispora, Playfordiaspora, Goubinispora, Lunatisporites, Osmundacidites, Nidipollenites, Podocarpidites, Inaperturopollenites* etc. The Tamia palynoassemblage-B differs from Dubrajpur palynoassemblage-A in lacking *Rajmahalispora, Diveripunctites, Tigrisporites*, etc.

The Lower Triassic palynoassemblages of Panchet Formation have been recorded by Bharadwaj and Tiwari (1977) from Bore-hole NCRD-6 in Dishergarh-Asansol region, Tiwari and Singh (1983, 1986), Singh and Tiwari (1982), Singh (1984). The quantitatively important genera in Group II in the East Raniganj coalfield are: *Falcisporites, Alisporites, Klausipollenites, Lunatisporites, Weylandites, Lundbladispora, Densoisporites, Playfordiaspora, Goubinispora* etc. They further subdivided into five sub-groups from bottom to top. Group II A & B could be comparable with Tamia palynoassemblage-B in having *Falcisporites, Weylandites, Alisporites, Satsangisaccites, Klausipollenites, Playfordiaspora, Goubinispora*, etc. They are also present in Assemblage-B of Pachmarhi beds of Tamia scarp.

Srivastava and Jha (1988, 1990, 1995) recorded Early Triassic palynomorphs from BH-GBR-7 (214m) and GAM-7 Mailaram areas respectively in Godavari Graben. Apart from the dominance of *Lunatisporites* or *Striatopodocarpites* the palynoassemblages contain significant Triassic elements, viz., *Falcisporites, Playfordiaspora, Klausipollenites, Alisporites* which are also present in Palynoassemblage-B of Tamia scarp.

Palynozone-3 established by Srivastava and Bhattacharyya (1996) closely compares with Assemblage-B of Tamia Ghat Road in having prominence of *Falcisporites*. However, the former does not contain *Playfordiaspora, Brachysaccus, Staurosaccites*, etc.

Nandi (1994) assigned *Falcisporites - Klausipollenites - Lundbladispora* Assemblage zone in the Pachmarhi Formation. Kumar (1995) recorded palynomorphs from Chota Mahadeva of Tamia scarp. Qualitatively palynoassemblage closely compares with the presently studied palynoassemblage-B in having *Falcisporites, Satsangisaccites, Alisporites, Klausipollenites, Playfordiaspora, Goubinispora (=Trochosporites), Inaperturopollenites, Weylandites* etc.

Prasad and Jain (1994) recorded palynofossils from wells of Krishna-Godavari basin. The significant Triassic elements viz., *Goubinispora, Playfordiaspora, Falcisporites, Klausipollenites, Chordasporites, Staurosaccites, Weylandites* etc. of K-G basin are also present in Pachmarhi Formation of Satpura basin.

DISCUSSION AND CONCLUSION

The Permo-Triassic palynoassemblages A & B have been identified in the Tamia Ghat Road section at Tamia in Chhindwara district of Madhya Pradesh. Palynoassemblage -A pertains to the Bijori Formation of Satpura basin contains the higher incidence of striated disaccate pollen viz. *Striatopodocarpites, Faunipollenites* along with *Striatites, Striamonosaccites, Rhizomaspora, Crescentipollenites, Distriatites, Cuneatisporites* etc., The presence of some nonstriated disaccate pollen viz., *Alisporites, Klausipollenites* as well as taeniate *Lunatisporites, Guttulapollenites, Corisaccites* and eusaccate pollen *Playfordiaspora* and meagre representation of trilete spores *Lophotriletes, Leiotriletes, Callumispora, Cyclogranisporites* etc. These qualify with the Late Permian palynoassemblages of Raniganj Coalfield of Damodar basin, Palynoassemblage zone III of Godavari basin, Palynozones - 1 & 2 of Kamthi coalfield, Nagpur, Sehra nala section of Son Graben, Sukhtawa section of Satpura basin, Upper Permian of South Africa and Australia.

Thus Palynoassemblage-A of Tamia section pertains to Bijori Formation could be assigned to be Late Permian age.

The Palynoassemblage-B of Tamia section contains the higher incidence of nonstriated disaccate pollen, viz., *Falcisporites, Satsangisaccites, Alisporites, Podocarpidites, Chordasporites, Klausipollenites* and presence of some significant palynomorphs, viz., *Weylandites, Goubinispora, Lunbdladispora*, etc., indicting a vegetational change which are characteristic of the younger flora and presence in low frequency of older striated disaccate forms indicating the beginning of younger flora of Early Triassic age (Scythian). The occurrence of *Staurosaccites* and *Brachyascus* further suggests that the palynoassemblage-B might have touched an early Middle Triassic part or extended upto Anisic-Ladinic age.

Thus the Tamia Ghat Road palynoassemblage-A and B were deposited during late Late Permian (Bijori Formation) and Early to early Middle Triassic age for Pachmarhi Formation respectively.

Palaeoenvironment:

Palaeoenvironment during the Permo-Triassic period in the Satpura basin had two different type of climate. One during the Upper Permian time when the argillaceous facies of Bijori Formation was laid down and the other the arenaceous facies of Lower Triassic Pachmarhi Formation was deposited in the basin. Crookshank (1936) opined that underlying Motur Beds were lacustrine deposits and the overlying Bijori Beds containing coal seams and thick carbonaceous shales indicated renewal of swampy conditions. As the swampy period was over the Satpura basin was elevated and partially denuded only to sink again for the sedimentation of the Upper Gondwanas. He further stated that southern boundary of the Pachmarhi Formation extended up to Tamia cliff as a huge sandbank which laid down along the southern shore of the Gondwana lake. The cliffs near Tamia banked up against a rapidly rising Bijori slopes. The rocks of Tamia scarp are exclusively sandstones (coarse grained and white) with thin layers of red coloured clays. Sandstones are separated from one another by layers of white quartz pebbles. Angular chips of felspar are sometimes present in the coarse layers. The occurrence of current bedding and absence of ripple markings suggest shallow water lake but had a greater depth than that of the lake in which Bijoris were laid down.

Singh, I.B. (1976) on lithological features, surmised that warm, humid climate (subtropical to tropical humid) was prevailing during the Bijori sedimentation (similar to Raniganj of Damodar basin). Mahadevas are mainly dominated by coarse grained (white) sandstones, red beds and conglomerates indicating rapidly flowing rivers and red coloured shales towards the same type of climate as the Panchet i.e. subtropical with pronounced seasonal droughts.

Shah (1976) suggested that the occurrence of amphibian, *Gondwanosaurus bijoriensis* in the Bijori Formation (Late Permian) indicate that there was water for some part of the year. The occurrence of estheriids (small) in the Pachmarhi Formation suggest warm and moist conditions with frequent drying up of the basin. Megafloral evidences in the Bijori Formation indicate a warm humid climate as it contains luxuriant vegetation of *Glossopteris* flora (Lele, 1976) but scanty occurrences of plant remains which are badly preserved indicating semiarid warmer climate with gradual drying up of the basin.

Palynofloras recovered from the carbonaceous shales of Bijori Formation and khaki olive clay of Pachmarhi Formation possess striated and nonstriated pteridospermic/gymnospermic disaccate pollen and poor occurrence of trilete spores. The pteridospermic and gymnospermic disaccate haploxylonoid pollen are indicating upland vegetation brought through the wind and deposited by water channels in the basin. Ueno (1958, 1979), Tiwari (1982), Tiwari and Tripathi (1987), viewed that haploxylonoid sacci bearing pollen grow well in cool temperate and subpolar or sub alpine zone, whereas taeniate pollen and flange bearing spores are indicative of warmer/dry conditions with seasonal fluctuations at low lying areas.

CONCLUSION

1. Sediments of Bijori Formation exposed at Tamia indicate a Permo-Triassic influence having warmhumid climate, deposited under swampy conditions with gradual drying up of the basin.
2. Sediments of Pachmarhi Formation deposited as a huge sand bank of Tamia cliff having warm, semiarid climate and prolonged seasonal droughts with continental conditions point towards the Triassic influence of Middle Gondwana.

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