Permian palynological assemblages in the Godavari Graben

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Palynological investigations carried out in the Godavari Graben during the last three decades have led to suggest the existence of nine palynozones from the Talchir to Kamthi formations. The Talchir Formation palynological assemblage, though dominated by the presence of radial monosaccate pollen grains, exhibits evidences of fluvio-glacial and lacustrine environment of deposition alongwith periodical influence of marine incursions. The presence of Karharbari and Barren Measures (Kulti) as distinct formations has been substantiated with palynological data. The occurrence of *Corisaccites-Guttulapollenites* palynozone and *Densipollenites* palynozone in the Middle Member of the Kamthi Formation represents the uppermost Permian palynoflora in Godavari Graben.

Key-words—Palynology, Permian, Godavari Graben (India)

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सारांश

गोदावरी द्रोणिका में परमी युगीन परागाणविक समुच्चय

सुरेश चन्द्र श्रीवास्तव

पिछले तीन दशकों में गोदावरी द्रोणिका में किये गये परागाणविक अन्वेषण से तलचीर से कामथी शैल-समूहों तक में नौ परागाणुमंडलों की उपस्थिति व्यक्त हुई है। हालाँकि तलचीर शैल-समूह अरीय एककोष्ठीय परागकणों से प्रभावी हैं, नदीय हिमानी एवं सरोवरी निक्षेपणीय वातावरण की विद्यमानता करते हैं। ये अवसाद समय-समय पर समुद्री अतिक्रमण से प्रभावित रहे हैं। परागाणविक आँकड़ों के आधार पर करहरबारी एवं बेरन मेजर्स (कुल्टी) की उपस्थिति विभिन्न शैल-समूहों के रूप में प्रस्तावित की गई है। कामथी शैल-समूह के मध्य सदस्य में **कोरिसेक्काइटिस-गुट्टुलापोलिनाइटिस** तथा **डेन्सीपोलिनाइटिस** नामक परागाणुमंडलों की उपस्थिति से गोदावरी द्रोणिका में उपरितम् परमी परागाणुवनस्पतिजात की विद्यमानता इंगित होती है।

THE Godavari Graben bounded by latitudes 16°38′ and longitudes 79°12′ and 79°39′ is a major graben trending NNW-SSE and covers an area of about 17,000 sq km. This graben is unique in the sense that it is the major coal producing area, south of Narmada River and there is a geological continuity of the Gondwana sediments from one extremity to the other having a well-defined constriction in the Paluncha-Kothagudem sector. Few outliers exist beyond this basin, viz., Yellandu, Kamaram and Tallada/Tiladru.

The Permian sediments in the main Godavari Graben are exposed along both the margins while the overlying sequence covers the axial portions. Archean rocks form the basement mainly in the northern part of the basin, while the Pakhal and Sullavai group of rocks constitute the basement north of the Mailaram High. However, the Archean rocks occur in faulted contact in the northern part around Ramagundam and east of Sirpur. Except for a limited exposure of the Permian sediments, major part of the sequence lies concealed below the surface as a result of which the lithostratigraphy in Godavari Graben has remained a matter of discussion. The transition between older to younger formations is gradational and it is difficult to draw inter-formational boundaries.

The geological set up of the Permian sequence initially defined by King (1881) has been later modified by various authors but the most commonly accepted one is that of Raja Rao (1982) which has

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been followed in the present review. The lithostratigraphic set up described by Raiverman *et al.* (1985) covers the entire Pranhita-Godavari Valley extending further north to the Wardha Valley coalfields and includes a number of new formations whose relationship with the known lithostratigraphic units is not clearly defined. Kutty *et al.* (1988) prefered to restrict the term Kamthi Formation to the lithologically distinct Upper Member of the Kamthi Formation (*sensu strictu* Raja Rao, 1982). They designated Infra-Kamthi to accommodate the strata between Barakar Formation and the Middle Member of the Kamthi Formation which is a well-defined lithostratigraphic unit. Recently, Lakshminarayana and Murty (1990) have proposed the stratigraphic set up for the Chintalpudi sub-basin which almost agrees with that described by Ramanamurty (1985) from Ramagundam area. However, he has overlooked the presence of Barren Measures (Kulti) and Raniganj equivalent sediments, which may possibly exist in Chintalpudi sub-basin.

TALCHIR FORMATION

This forms the lowermost unit of the Permian sediments and is exposed in narrow strips along the western margin near Mandaram to Lingala, while on the eastern margin they occur near Cherla-Manuguru sector besides a few small occurrences within the basin. Near Mancherial, these rocks are exposed in Chintala stream and railway cutting leading to Mandamari Power Station. The basal tillite beds comprise polymictic clasts in a fabric of mixed grain size and are overlain by siltstone, khaki green splintery shale and sandstone. These tillites suggest ancient glaciated moraines. Recurrence of tillite bed is also reported (Raja Rao, 1982). The siltstone gets coarser in the younger part of the sequence and exhibit cross laminations. In few bore-holes in Ainapallam area grey black splintery shales containing *Gangamopteris* leaf-impressions have been observed.

BARAKAR FORMATION

The sediments pertaining to Barakar Formation are exposed to a very limited extent and occur as discontinuous patches along the basin margins. It has been divided into two members:

1. *The Lower Member*—It is characterised by coarse-grained sandstone including lenses of conglomerates, carbonaceous shales and coal seams.
2. *The Upper Member*—It constitutes a large scale cross stratified sandstone with inter-bedded carbonaceous shales and coal seams. The present mining of coal is largely confined to this horizon.

BARREN MEASURES (KULTI) FORMATION

Sengupta (1970) demarcated the Barren Measures within the basal part of the Kamthi Formation and it was later established as a persistent horizon overlying the Barakar and underlying the Kamthi Formation. It is characterised by cross bedded medium to coarse-grained, greenish to grey white sandstone, variegated clays, etc. These sandstones turn brown when exposed on the surface. Kutty *et al.* (1988) included it as a basal unit of the Infra-Kamthi Formation.

KAMTHI FORMATION

The sediments overlying the Barren Measures (Kulti) and underlying the Maleri Formation are now referred to as the Kamthi Formation (Raja Rao, 1982) and form the thickest horizon in this coalfield. Based on lithologic attributes it has been divided into three members: (i) *The Lower Member* is marked by grey white sandstone which gets calcareous at intervals. These sandstones are interbedded with thick to thin coal seams. The Sondila Seam near Sondila Village corresponds to this member. The occurrence of this member has been proved in Ramakrishnapuram, Mantheni, Ramagundam, Manuguru, Mailaram, Budharam and Ainapallam-Gompana areas and contain coal seams; (ii) *The Middle Member* contains a cyclic sequence of grey-white cross-bedded sandstone, shale, variegated clays which exhibit greenish tint at places. These sandstones sometime show erosional surfaces at their bases. The shales often contain calcareous nodules/concretions; (iii) *The Upper Member* is distinguished by coarse-grained sandstone and brick-red siltstone, clays, etc. This member often overlaps all the other older formations at places.

PALYNOLOGY

Palynological studies in the Godavari Graben started as early as 1962 when Thiergart and Frantz (1962) recorded some pollen and spores from the Kothagudem Coalfield. Ghosh (1968) worked out the vertical and lateral variations of spores and pollen in Ross and Salarjung seams from Tandur area. Subsequently Tiwari and Moiz (1971) described five new taxa. Ramanamurty (1979) while reporting the occurrence of a coal seam in the

Kamthi Formation from Ramagundam area mentioned some trilete spores and striate and nonstriate pollen.

During the past decade systematic work has been carried out at the Birbal Sahni Institute of Palaeobotany and considerable data has accumulated relating to Permian and Permian-Triassic sediments of the Godavari Graben. Occurrence of megaspores (Jha & Srivastava, 1984) and a new taeniate-monosaccate pollen *Kamthisaccites* (Srivastava & Jha, 1986) have been recorded from the Permian sediments. Recently Rama Rao *et al.* (1990) have also dated the Permian sediments of the Chintalpudi sub-basin on the basis of palynological studies. Palynological assemblages recorded from different levels are summarised in Table 1.

Table 1—Permian palynozones in Godavari Graben, Andhra Pradesh

LITHOZONE		PALYNOZONES				STANDARD
FORMATION	MEMBER	PALYNOZONE	DOMINANT TAXA	SUBDOMINANT TAXA	QUALITATIVELY IMPORTANT TAXA	PALYNOZONE
Kamthi	Middle	10	*Striatopodocarpites* *Faunipollenites*	*Densipollenites*	*Crescentipollenites* *Marsupipollenites* *Chordasporites* *Lunatisporites* *Falcisporites* *Klausipollenites*	Raniganj
		9	*Striatopodocarpites* *Faunipollenites*	*Corisaccites* *Guttulapollenites*	*Densipollenites* *Lunatisporites* *Falcisporites* *Vitreisporites*	
		8	*Striatopodocarpites*	*Parasaccites*	*Densipollenites* *Corisaccites* *Guttulapollenites*	
		7	*Faunipollenites*	*Striasulcites*	*Densipollenites* *Falcisporites* *Polypodiidites* *Osmundacidites*	
	Lower	6	*Faunipollenites* *Striatopodocarpites*	*Labirites* *Verticipollenites*	*Distriatites,* *Hindipollenites* *Hamiapollenites* *Lueckisporites* *Gondisporites* *Weylandites* *Marsupipollenites*	
Barren Measures (Kulti)		5	*Faunipollenites* *Striatopodocarpites*	*Densipollenites* *Scheuringipollenites*		Kulti
Barakar	Upper	4	*Scheuringipollenites* *Brevitriletes*	*Indotriradites* *Hennellysporites* *Horriditriletes*	*Primuspollenites* *Striatites* *Tiwariasporis* *Latosporites*	Lower Barakar
	Lower	3	*Parasaccites*	*Scheuringipollenites*	*Brevitriletes*	Upper Karharbari
		2	*Callumispora*	*Parasaccites*	*Brevitriletes* *Indotriradites*	Lower Karharbari
Talchir		1	*Parasaccites*	*Plicatipollenites*	*Leiosphaeridia* *Vestigisporites* *Virkkipollenites* *Caheniasaccites* *Jayantisporites*	Talchir

Talchir Formation

The Talchir Formation palynological assemblage is dominated by the presence of radial monosaccate pollen. This assemblage has been recovered from siltstone, banded shale, etc. In bore-hole GRK-1 (825-807 m) and GRK-24 (853.55-826.65 m) from Ramakrishnapuram area *Leiosphaeridia* occurs in higher percentages alongwith monosaccate pollen. Rawat and Jain (1985) reported similar assemblage alongwith *Botryococcus* and foraminifers from Chandrapur area. The leiosphaerid associated assemblage has been considered to indicate marine influence during the deposition of Talchir sediments in Palar Basin and Bap Formation, Rajasthan (Venkatachala & Rawat, 1973, 1984, respectively). In Manendragarh area (Bharadwaj, Srivastava & Anand-Prakash, 1979) *Leiosphaeridia* and spinose acritarchs (*Micrhystridium*) occur together in *Eurydesma-Counularia* associated sediments. The grey-black splintery shale present at the top of the Talchir Formation in bore-hole GAG-1 from Ainapallam-Gompana area which contains well preserved *Gangamopteris* leaf impressions (personal observation) is lithologically comparable to the black needle shale of the Talchir Formation from Manendragarh which contain invertebrate marine fossils. In Mohpani Coalfield Bharadwaj and Anand-Prakash (1972) also observed the presence of similar shales at the top of the Talchir Formation. These records suggest a marine transgression during the deposition of the younger sediments of the Talchir Formation in Godavari Graben. The basal tillite in the older part has not yielded palynofossils.

Barakar Formation

The Lower Member of the Barakar Formation in Godavari Graben, characterised in general by coarse-grained gritty sandstone, shale and coal, is comparable to the Karharbari sediments of the type area, the Giridih Coalfield. In Godavari Graben the Karharbari sediments have not been marked as a mappable unit, though the microflora occurs persistently in the Lower Member of the Barakar Formation overlying the Talchir (Ramakrishnapuram area, GRK-1 : 798.90-795.60 m; GRK-24 : 775.55-645.20 m; GRK-25 : 676.50 m; Ramagundam area, GGK-20 : 854.00-827.25 m; Ainapallam area GAG-1 : 436.00-202.60 m; Manuguru area—Thick Seam; Kothagudem and Yellandu areas—King Seam). Since sediments pertaining to this horizon are exposed to a limited extent, the recognition of Karharbari as a formation in Godavari Graben has not been given much attention. However, based on palynological studies, a Karharbari palynozone is identifiable.

In recent years leiosphaerids have been recorded in the Karharbari sediments from Umaria Coalfield (Venkatachala & Tiwari, 1988). Banerjee (1988) also reported brackish water acritarchs including *Leiosphaeridia* from Rajmahal Basin. Chaudhuri (1988) suggested a marine influence in Hutar Coalfield on the basis of foraminifera and evaporites. In Godavari Graben also *Leiosphaeridia* alongwith monosaccate pollen grains in Upper Karharbari palynozone have been observed in Ainapallam area (Bore-hole GAG-1). All these records represent marine influence during the Upper Karharbari palynozone.

The Upper Member of the Barakar Formation lithologically exhibit a repeated cyclothem and contains the important coal seams from Belampalli-Kothagudem areas. The palynoflora contained in these sediments compare the Lower Barakar palynoflora (Srivastava, 1987; Srivastava & Jha, 1989). The Upper Barakar palynoflora has not been encountered in any bore-hole studied from the Godavari Graben.

Barren Measures (Kulti) Formation

The palynoassemblage of the Kulti Formation has been observed in Ramakrishnapuram area (boreholes GRK-1 : 493.57-109.45 m; GRK-24 : 515.75-363.70 m; GRK-25 : 582.70 m) and Ramagundam-Mantheni area (bore-hole GGK-20 : 628.44-215.00). In all these boreholes a complete epibolic development of *Densipollenites* is present between the underlying Barakar and overlying Kamthi sediments. This palynozone is comparable to the known Kulti palynozone of the Jharia Coalfield (Bharadwaj *et al.*, 1965).

Kamthi Formation

The Lower Member containing palynozone 6 has been recorded in a number of bore-holes (Srivastava & Jha, 1988) and is comparable to the Raniganj palynoflora of the Damodar Valley. In Ramagundam area, a thick coal seam known as Sondila Seam has been suggested to belong to this palynozone (Bharadwaj *et al*, 1987). In the Chintalpudi sub-basin thick coal seams encountered in the younger part of the bore hole GAG-1 also contain similar palynoflora.

Palynozones 7-10, as shown in Table 1, occur within the younger part of the Lower Member and older part of the Middle Member of the Kamthi Formation and in general compare to the younger Raniganj palyozones of the Damodar Valley except some significant variations (Bharadwaj, Tiwari & Anand-Prakash, 1979). However, palynozones 8-9 are more comparable to the palynoflora of the Bijori

Formation in Satpura Basin (Bharadwaj *et al.*, 1978) and Chidru Formation, Salt Range (Balme, 1970) in view of the higher incidence of *Corisaccites* and *Guttulapollenites*. *Striasulcites* palynozone (Palynozone 7) is not reported so far from any other basin. Reoccurrence of *Parasaccites* (Palynozone 8) alongwith striate-disaccate pollen is also known from the Godavari Graben only. In addition to these, *Iraquispora, Triquitrites, Taeniaepollenites, Phidiaesporites, Concavissimisporites* and *Columinisporites* found in the Godavari Graben have not been observed in other peninsular basins of India.

DISCUSSION

The sedimentation of the Permian sequence in Godavari Graben appears to have been initiated by the deposition of tillite beds at the base of the Talchir Formation. Some of the clasts embedded in it show polished surfaces and striations indicating glaciation (Ramanamurty, 1985). Palynological records are not available at this level of sedimentation but following glaciation fluvio-glacial and lacustrine environment developed permitting a thick pile of lacustrine deposits. Palynological assemblages indicate periodic marine incursions as is evidenced by the occurrence of *Leiosphaeridia*, foraminifers, etc. The possible gate-way for these marine incursions could have been from the eastern sea bay along the Krishna-Godavari lineament. The radial monosaccate dominant assemblage pertaining to gymnosperms also suggests a cool humid environment.

The Talchir Formation is overlain by the Barakar Formation during which the sedimentation pattern was dominantly fluvial and a luxurient flora appears to have existed which led to the development of rich coal-forming swamps. In the Lower Member of the Barakar Formation the lithologic association is distinctly different from that of the Upper Member and is comparable to the Karharbari sediments; it has remained a debatable unit so far on the Godavari Graben. Basu (1964) has suggested the occurrence of Karharbari coal seams in Godavari Graben but since then it has not been identified as a separate unit. The palynological records also suggest the existence of Karharbari sediments among the coal seams which are being worked out in various mines (Srivastava, 1987) and also subsurface sediments of Ramakrishnapuram, Budharam, Manuguru, Mailaram and Kothagudem areas. The palynological assemblages thus provide enough evidence to identify Karharbari's in Godavari Graben.

The Upper Member of the Barakar Formation is the principal coal-bearing horizon in Godavari Graben. The palynoflora recorded in these sediments compare with the Lower Barakar palynoflora of other basins (Tiwari, 1974). In boreholes GRK-1, GRK-24 and 25 and GGK-20 the Lower Barakar palynozones are immediately succeeded by the Barren Measures (Kulti) palynozone, thus indicating the possible absence of the Upper Barakar palynozones in Godavari Graben.

The sediments overlying the Barakar and underlying the Maleri formations have been classified into Barren Measures and Kamthi Formation by Raja Rao (1982). Kutty *et al.* (1988) included the former as a basal unit (Lithozone 1) of the Infra-Kamthi Formation and considered the Upper Member of the Kamthi Formation of Raja Rao (1982) as Kamthi Formation in view of its distinct lithology. Sengupta (1970) recognised Barren Measures as a distinct unit which was later accepted by Raja Rao (1982). Ramanamurty (1985) also preferred to maintain it as a separate unit on the basis of lithology and heavy minerals and suggested that the deposition during Barren Measures was largely under braided system with rapid sedimentation. These sediments have yielded a striate disaccate rich assemblage having epibole zone of *Densipollenites* which is characteristic of Barren Measures palynoflora of Damodar Valley. The thickness of Barren Measures appears to be maximum (450 ± 50 m) around Ramagundam-Mantheni area while in the rest it is highly variable. The sediments being essentially arenaceous do not yield palynofossils, in general. In the same way recognition of this formation as a separate unit in other areas has remained elusive. Nonetheless the lithological suit attributed to Barren Measures Formation is distinct from the underlying Barakar and overlying Kamthi Formation both of which are coal-bearing horizons.

The Kamthi Formation (*sensu* Raja Rao, 1982) attains its maximum thickness ($\pm$ 1600 m) around Ramagundam-Mantheni area (Ramanamurty, 1985). The Lower Member has been proved to be coal-bearing while the Middle and Upper Members are devoid of coal. Palynozone 6 is restricted to the coal-bearing Lower Member, palynozones 7 and 8 transgress the Lower and Middle Members and palynozones 9 and 10 occur only in the older part of the Middle Member. The Permian-Triassic transition occurs within the Middle Member of the Kamthi Formation. Lithozone-2 of the Infra-Kamthi Formation (Kutty *et al.*, 1988) appears comparable to the Lower Member of the Kamthi Formation (*sensu* Raja Rao, 1982) while Lithozones-3 and 4 of the Infra-Kamthi Formation may be considered

equivalent to the Middle Member of the Kamthi Formation. Kutty *et al.* (1988) have described vertebrate fossils, viz., *Endothiodon* and *Cistecephallus* from the Lithozone-3 and have correlated it with the *Cistecephallus* Zone (Beaufort Formation) of South Africa. Lithologically, Lithozone-3 of the Infra-Kamthi Formation compares with the older part of the Middle Member of the Kamthi Formation. Palynozones-9 and 10 described here occurs in this unit and represent almost the youngest Upper Permian palynozone. Ramanamurty (1985) considered the lithological set up of the Lower Member of the Kamthi Formation equivalent to the Raniganj Formation while Upper and Middle Members being equivalent to the Panchet and Mahadeva formations of the Damodar Valley. However, occurrence of *Cistecephallus* fauna and also *Densipollenites* rich palynoassemblage extends the Upper Permian sequence further up in the older part of the Middle Member. Srivastava and Jha (1988, 1989) recorded Lower Triassic palynoflora from the upper part of the Middle Member of Kamthi Formation. Thus it was observed that the Permian-Triassic transition occurs right in the Middle Member.

The Upper Member of the Kamthi Formation is distinguishable by its characteristic lithology. Raja Rao (1982, p. 15) mentioned the presence of fragmentary remains of *Ptilophyllum* (earlier observed by C. Nageswar Rao) in Jaipuram Ridge. In recent years a vertebrate skull (Daptocephalid dicynodont?) was discovered among the sandstones of this member near Jaipur Village (GSI News, Coal Wing, January, 1986) which indicates the occurrence of Late Permian sediments. Well-preserved, though scanty, leaf-impressions of *Glossopteris* have also been observed in ferruginous shales in sandstone quarries near Jaipur Village. The size of the leaf is small as compared to those occurring in the Upper Permian sequence. With these varied evidences it appears difficult to correlate the Upper Member but considering the palynological evidences it appears probable that this member may be equivalent of the Supra-Panchet/Mahadeva formations of the Damodar Valley.

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