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AGE OF THE KOTA FORMATION, PRANHITA-GODAVARI VALLEY, INDIA : A PALYNOLOGICAL APPROACH

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ABSTRACT

Palynological investigations have been carried out on four outcrop sections of the Kota Formation that include the type section near Kota village, and others near Metpalli, Manganpalli and Paikasigudem villages in Pranhita-Godavari Valley, India. In all the productive samples of these four sections, the pollen genus *Calliallasporites* is the common element. However, the presence of certain marker species in each outcrop has helped in age evaluation. In the Metpalli section, the assemblage is non-diversified. Records of *Contignisporites cooksoniae*, and *Murospora florida* in the Kota type section; *Crybelosporites stylosus and* cf. *Aequitriradites* sp. in the Manganpalli section; and *Coptospora microgranulosa, and Crybelosporites punctatus* in Paikasigudem section, indicate that the Kota Formation is a time transgressive lithological unit deposited during the late Mid Jurassic to Early Cretaceous. The non-diversified spore-pollen composition in each deposit seems due to shallow water deposition.

Key words : Kota Formation, P-G Valley, Spores-pollen, Jurassic, Cretaceous.

INTRODUCTION

In the Pranhita-Godavari Valley, the Gondwana rocks occur in an intracratonic rift that is nearly 50 km wide. Here the Upper Gondwana sequence has been divided into, from oldest to youngest, the Yerrapalli, Bhimaram Sandstone, Maleri, Dharmaram, Kota, Gangapur and Chikiala formations (Kutty, 1969). Among these, the Kota Formation has gained an important place in stratigraphy, because of its rich vertebrate fauna. It has an unconformable relationship with the older Dharmaram and younger Gangapur formations respectively. A number of outcrops of the formation are exposed in discrete patches and strips in Pranhita-Godavari valley.

The Kota Formation is primarily composed of coarse to fine grained pebble sandstones, and yellowish green clays and mudstones at the base, followed upwards by grey, creamy, bedded limestones, which are overlain by ferruginous clays, mudstones, siltstones and sandstones. The limestones and underlying clays and siltstones have yielded a rich assemblage of vertebrates, invertebrates and charophytes. For these to be put into a stratigraphic context, a better understanding of the depositional time span for the Kota sediments is necessary, and is the aim of the paper.

PREVIOUS WORK

Because of its rich faunal record, the Kota Formation has been the focus of intensive palaeontological investigation during the last three decades. Various groups of fossils representing semionotid, pholidophorid and coelacanthid fishes, sauropod dinosaurs, and some remains of flying reptiles and rare early mammals have been reported from it. An Early Jurassic ('Upper Lias') age has been proposed based on semionotid fishes (Jain, 1973, 1980) and a flying reptile (Jain, 1974). This age assignment has been accepted by many workers (Yadagiri and Prasad, 1977; Datta, 1981; Yadagiri, 1984, 1985, 1986; Prasad, 1986; Feist, Bhatia and Yadagiri, 1991; Bhattacharya, Ray, Dattta and Maulick, 1994; Prasad and Manhas, 1997). However, Govindan (1975) has favoured a Middle Jurassic age, based on ostracode fauna. This was subsequently supported by Misra and Satsangi (1979).

The only palynological record hitherto is from the type section of the Kota Formation. On the basis of a dominance of the *Classopollis* - group of pollen in the palynoassemblage, Prabhakar (1989) assigned an Early Jurassic age to the formation. Palynological data from outcrops of the overlying Gangapur Formation, which is of Early Cretaceous age, have, however, been published (see Vijaya, 1999).

SPORE-POLLEN COMPOSITION

In view of the conflicting dates resulting from the vertebrate and ostracod investigations, an attempt has been made to investigate the four most important outcrop sections for their palynofloral content. This includes the type section exposed near Kota village (KT), and others near the villages of Metpalli (MTP), Manganpalli (MPL) and Paikasigudem (PKG) in Pranhita-Godavari Valley (fig. 1 A and B). All these sampled sections correspond to the limestone zone of the Upper Member of the Kota Formation, (Table 1). Recovery of spores and pollen grains (Pl. I, figs 1-21) from the productive samples in the four sections is poor and in general the specimens are not well preserved. The total composition of the palynoassemblage from each section has been placed in two groups for the convenience of stratigraphic interpretation. Group-A species have long vertical ranges and are relatively frequent, whereas Group-B contains species that can play a key role in determining the chronostratigraphic position of the bed, in which these occur for the first time. The numbers of specimens found in each assemblage are given in brackets.

Metpalli (MTP) Section

(figs. 1 and 2; Table 2)

This section is located 500 m, west of Metpalli village and is about 19 m thick. Seventeen samples were collected from it (fig. 2). All yielded just a few specimens of spore and pollen grains. Among these, the genus *Callialasporites* occurs frequently along with *Araucariacites australis,* other species are rare (Table 2); hence this assemblage has been referred to as Group A.

Remarks: The impoverished spore-pollen composition of the Metpalli assemblage is of little biostratigraphic significance.The presence of *Callialasporites* throughout the bed is consistent with a Jurassic age determination. But the precise age correlation could not be ascertained due to the

EXPLANATION OF PLATE I ⟶

Spore-pollen species identified in the productive samples from the sections exposed near the villages of Metpalli, Kota, Manganpalli and Paikasigudem (Kota Formation) in Pranhita-Godavari Valley. All are x600, unless otherwise stated.

1. *Callialasporites dampieri* (Balme) Dev, 1969. Slide No. BSIP 12356.
2. *Callialasporites segmentatus* (Balme) Dev, 1961. Slide No. BSIP 12371.
3. *Callialasporites triletus* Singh, Srivastava and Roy, 1964. Slide No. BSIP 12371.
4. *Contigisporites multimuratus* Dettmann, 1963. Slide No. BSIP 12367.
5. *Concavissimisporites kutchensis* Venkatachala, 1969, Slide No. BSIP 12355.
6. *Baculatisporites comaumensis* (Cookson) Potonie, 1956. Slide No. BSIP 12354
7. *Contignisporites cooksoniae* (Balme) Dettmann, 1963. Slide No. BSIP 12369A.
8. *Duplexisporites problematicus* (Couper) Playford and Dettmann, 1965. Slide No. BSIP 12368x500.
9. *Rugulatisporites* sp. Slide No. BSIP 12351 x500.
10. *Lycopodiacidites dettmannae* Burger, 1980. Slide No. BSIP 12374.
11. Cf. *Crybelosporites stylosus* Dettmann, 1963. Slide No. BSIP 12371.
12. *Callialasporites trilobatus* (Balme) Dev, 1961. Slide No. BSIP 12358.
13. *Podosporites tripakshi* Rao, 1943. Slide No. BSIP 12355 x500.
14. *Klukisporites venkatachalae* Tripathi, Tiwari and Kumar, 1990. Slide No. BSIP 12378.
15. *Murospora florida* (Balme) Pocock, 1961. Slide No. BSIP 12368 x600.
16. *Cooksonites rajmahalensis* Tripathi, Tiwari and Kumar, 1990. Slide No. BSIP 12380.
17. *Crybelosporites punctatus* Dettmann, 1963. Slide No. BSIP 12389.
18. cf. *Appendicisporites* sp. 1971. Slide No. BSIP 12389.
19. *Coptospora kutchensis* Venkatachala, 1969. Slide No. BSIP 12385.
20. cf. *Coptospora microgranulosa* Venkatachala and Sharma, 1974. Slide No. BSIP 12383.
21. cf. *Triporoletes* sp. Slide No. BSIP 12388.

Plate I

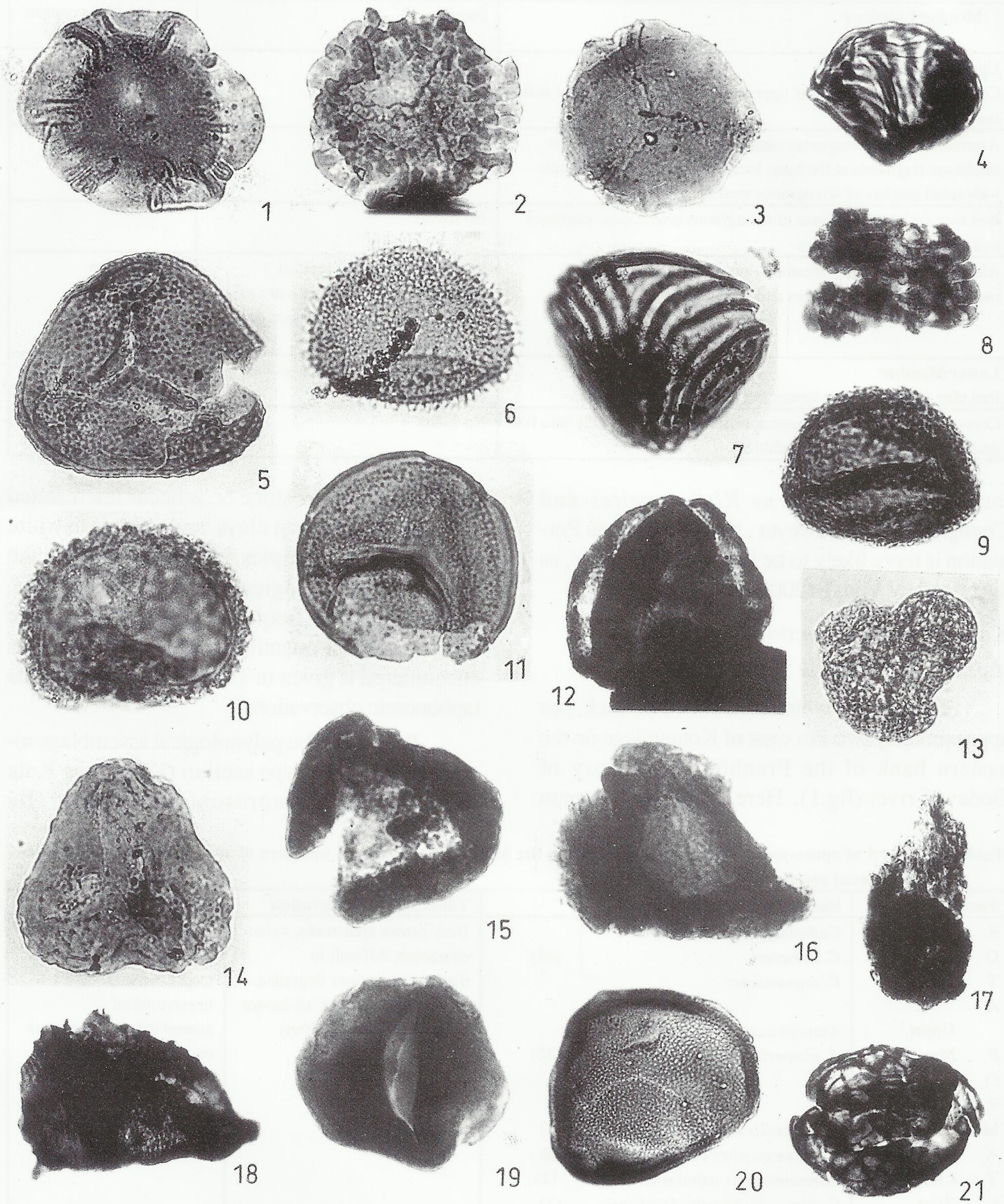

Table 1 : Lithological subdivision of the Kota Formation (Rudra, 1982).

Member/Lithology	Fossils	Stratigraphic position of studied sections
Upper Member Calcareous sandstone in the upper part, red clay intercalated with sandstone	Calcified wood	
Argillaceous and ferruginous sandstones containing abundant mudstone fragments at the base, locally pebbly / conglomeratic with small patches of ferruginous mudstones	Silicified wood	
Red clay with intercalations of ferruginous mudstones, siltstones and fine grained sandstones	No fossils	
Alternation of bedded limestone (locally laminated and with mudcracks), calcareous clays and mudstones	Fish, anerans, flying reptiles, mammals, corcrostracars, ostracodes, insects, charophytes stromatolites, fossil wood trace fossils	PKG Section MPL Section KT Section MTP Section
Lower Member Red clay with sandstone lenses and calcareous concretions	Dinosaurs, mammals, ostracodes, charophytes	
Coarse, pebbly calcareous sandstone that grades vertically into fine grained sandstone with few pebbles	No fossil	

lack of such genera as *Klukisporites* and *Contignisporites*; however , this part of Kota Formation is more likely to be late Middle Jurassic, as discussed by Vijaya (2000).

Kota Type (K/T) Section

(figs. 1 and 3; Table 3)

This section which is about 10 m thick, lies approximately two km west of Kota village on the eastern bank of the Pranhita, a tributary of Godavari river (fig.1). Here, a number of cream to pale yellow limestone beds occur intercalated with yellowish green clays and yellowish white marls. Eighteen samples were collected from the section for palynological study (fig.3). Of these, palynomorphs are frequent in 10 samples but rare in the rest. Semi-quantitative data on the species encountered is given in Table 3, along with some taphonomic observations.

Remarks: The palynological assemblage recovered from the type section (KT) of the Kota Formation is represented mainly by

Table 2 : Record of spore-pollen species recovered from the Metpalli Section. The numbers of specimens for each species encountered are given in bracket.

Formation		Species composition		Taphonomic observation	Remarks
K		*Callialasporites turbatus*		Dark brown specimens, exine characters difficult to distinguish, exines degraded. Woody matter blackish-brown of medium size (20-30m)	Poor yield; genus *Callialasporites* is the major constituent; impoverished assemblage. Quantitative count not feasible.
O		*C. dampieri*	(32)		
T		*C. segmentatus*			
A					
	Upper	*Araucariacites australis*			
F	Member	*A. ghuneriensis*	(30)		
O					
R					
M		*Classopollis classoioles*	(3)		
A		*Biformaesporites baculosus*	(2)		
T	Limestone	*Foraminisporis tribulosus*	(2)		
I	Zone	*Concavissimisporites kutchensis*	(2)		
O		*Microcachryidites antarcticus*	(4)		
N		*Podosporites tripakshii*	(1)		

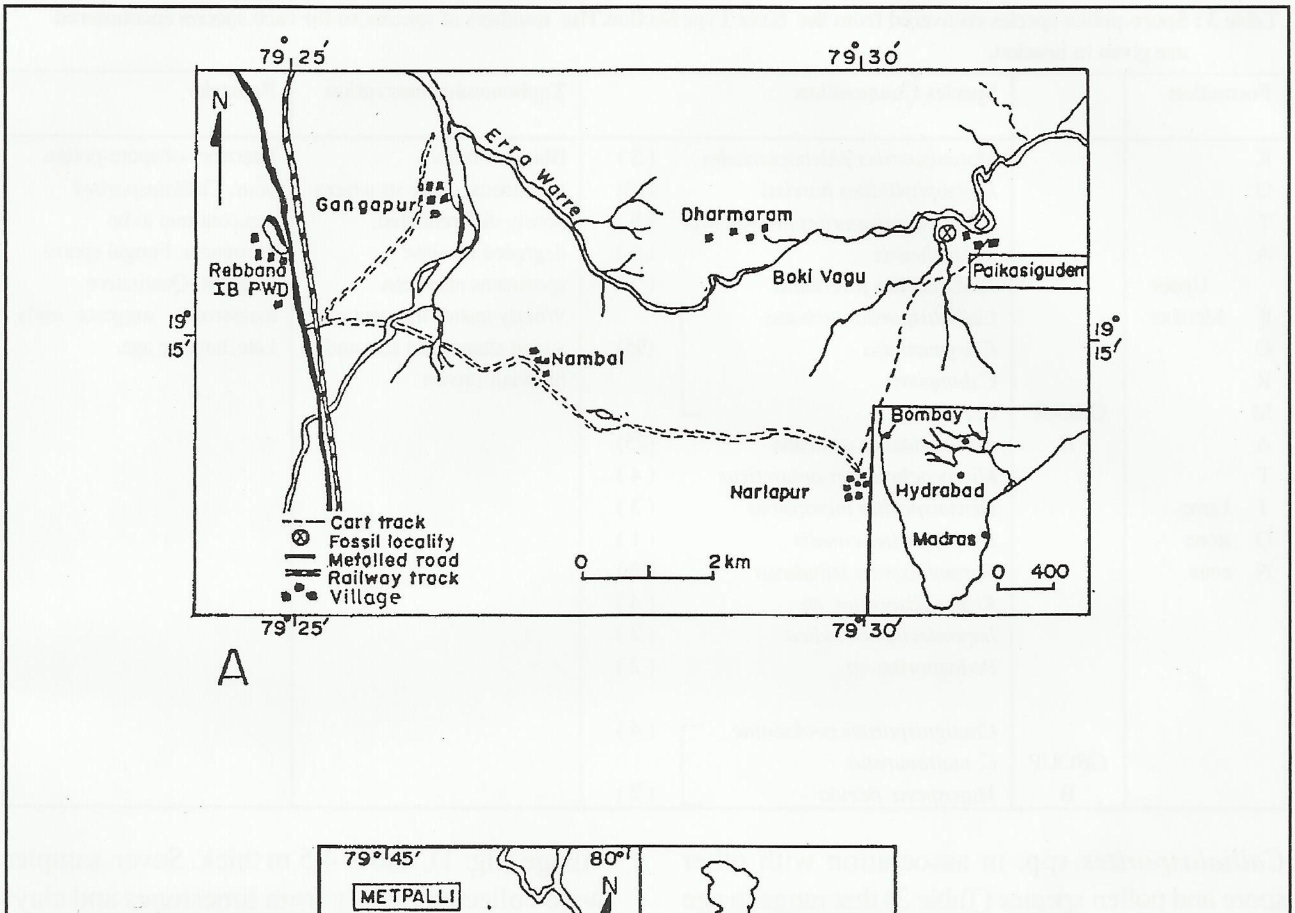

Fig.1. Map showing the location of the studied outcrop sections of the Kota Formation in the Pranhita-Godavari Valley. In part A, location of PKG section is shown, and in part B, other localities (MTP, KT, MPL) are given.

Table 3 : Spore-pollen species recovered from the Kota Type Section.The numbers of specimens for each species encountered are given in bracket.

Formation		Species Composition		Taphonomic observation	Remarks
KOTA FORMATION Upper Member Lime-stone zone	GROUP A	*Matonisporites phlebopteriodes*	(2)	Blackish-brown specimens; exine structures poorly differentiated, degraded Hyaline specimens also seen. Woody matter frequent of varied shape, and size and blackish-brown	Recovery of spore-pollen poor, *Callialasporites* spp.continue to be prominent. Fungal spores frequent. Qualitative assessment suggests early Late Jurassic age.
		Dictyophyllidites harrissi	(10)		
		Concavissimisporites penolaensis	(8)		
		C. kutchensis	(2)		
		Klukisporites foveolatus	(2)		
		Callialasporites turbatus *C.segmentatus* *C.dampieri* *C. triletus*	(95)		
		Araucariacites australis	(25)		
		Microcachryidites antarcticus	(4)		
		Densoisporites mesozoicus	(3)		
		Foveosporites canalis	(1)		
		Foraminisporis tribulosus	(3)		
		Kraeuselisporites sp.	(4)		
		Impardecispora indica	(2)		
		Podosporites sp.	(2)		
	GROUP B	*Contignisporites cooksoniae* *C. multimuratus*	(4)		
		Murospora florida	(2)		

Callialasporites spp. in association with other spore and pollen species (Table 3) that range in age from the Early Jurassic to Early Cretaceous. Records of *Contignisporites cooksoniae* and *Murospora florida* in the assemblage suggest a late Jurassic age, because the first occurrence levels (FADs) for these two species are Bajocian-Bathonian and Callovian respectively (see Vijaya, 2000). The FAD for *Contignisporites cooksoniae* is not traceable in this section, because the base is not exposed. The absence of *Cicatricosisporites australiensis*, a key species for the latest Jurassic (Tithonian) and Early Cretaceous, suggests that the Kota type section comprises sediments that were deposited earlier than this. Overall, the limited palynological evidence suggests that the type section is between the Callovian-Kimmeridgian in age (Table 7).

Manganpalli (MPL) Section

(figs 1 and 4; Table 4)

This section lies one km north of Manganpalli village (fig. 1), and is 4.5 m thick. Seven samples were collected mainly from limestones and clays (fig. 4). They all yielded well-preserved spores and pollen grains but the recovery was poor (Table 4). Again, *Callialasporites* is the main component of the assemblage, along with other Group A species which continue from the older horizons.The presence of *Crybelosporites stylosus* and *Aequitriradites* sp., however, is useful from the biostratigraphyic viewpoint,

Remarks : Although the spore-pollen assemblage is small and of limited diversity, *Crybelosporites stylosus* first appears in India and Australia towards the end of the Tithonian-Berriasian followed by incoming of *Aequitriradites hispidus* to document the Late Tithonian to Early Berriasian level in the Mesozoic Sequence (see Burger, 1995, Vijaya, 1999). Hence, the Manganpalli section is likely to encompass the Late Jurassic/Early Cretaceous transition (or the Late Jurassic/ Early Cretaceous boundary).

Table 4: Spore-pollen species recovered from the Manganpalli Section. The numbers of specimens for each species are given in bracket.

Formation		Species Composition		Taphonomic observation	Remarks
		Callialasporites turbatus		Golden brown to dark brown specimens; exine characters distinct. Woody matter golden brown, well preserved of medium size (20-30 m)	Poor yield, limited diversity. Frequent occurrence of *Callialasporites* spp. Qualitative assessment suggests that the succession encompasses the Jurassic/ Cretaceous transition.
		C. monoalasporous			
K		*C.segmentatus*	(40)		
o		*C. reticulatus*			
t Upper		*C. triletus*			
a Member		*Araucariacites australis*	(18)		
		Foveosporites canalis	(1)		
	GROUP	*Impardecispora indica*	(2)		
	A	*Baculatisporites comaumensis*	(1)		
		Concavissimisporites vaviverrucatus	(1)		
F		*Biformaesporites baculosis*	(2)		
o		*Osmundacidites singhii*	(2)		
r		*Klukisporites venkatachalae*	(2)		
m Lime-		*Lycopodiacidites asperatus*	(1)		
a stone		*Triletes tuberculiformis*	(2)		
t zone		*Trilobosporites purverulentus*	(2)		
I		*Dictyophyllidites harrisii*	(2)		
o		*Kraeuselisporites* sp.	(1)		
n	GROUP				
	B	*Crybelosporites stylosus*	(2)		
		Aequitriradites sp.	(1)		

Paikasigudem (PKG) Section

(figs. 1 and 5; Table 5)

A 20 m thick section is exposed about 500 m southwest of the village of Paikasigudem along a stream bank (fig.1). It consists of clays, siltstones, mudstones and thin limestone bands. In all, sixteen samples were collected from it for palynological processing (fig.5). Once more the assemblage is dominated by the specimens of *Callialasporites* in association with Group A species of common occurrence in older beds . Only a few species of stratigraphic value (Group B) were encountered.

Remarks: The presence of species in Group B (Table 5) indicates that the section is referrable to part of *Foraminisporis asymmetricus* palynozone, which encompasses the Hauterivian and Barremian stages (Dettmann *et al.*, 1992; see Vijaya, 1999). The composition of the palynoassemblage suggests a late Hauterivian - Early Barremian age-range.

The palynofossils recovered from this section are poorly preserved and biostratigraphically less significant. But this is the only section of the Kota Formation which has yielded a diversified microvertebrate assemblage represented by semionotid and elasmobranch fishes, sphenodontids, lizards, ornithischian and theropod dinosaur remains and mammals.

AGE IMPLICATIONS

As indicated in the preceding account, previous age assignments of the Kota Formation based on fishes, reptiles and palynomorphs are still the subject of discussion. A list of spores and pollen grains recovered from the four sections exposed near Kota, Metpalli, Manganpalli and Paikasigudem villages, is given in Table 6. Overall, the assemblages are both taxonomically and numerically impoverished, but some slide preparations contain a few species of biostratigraphic importance .

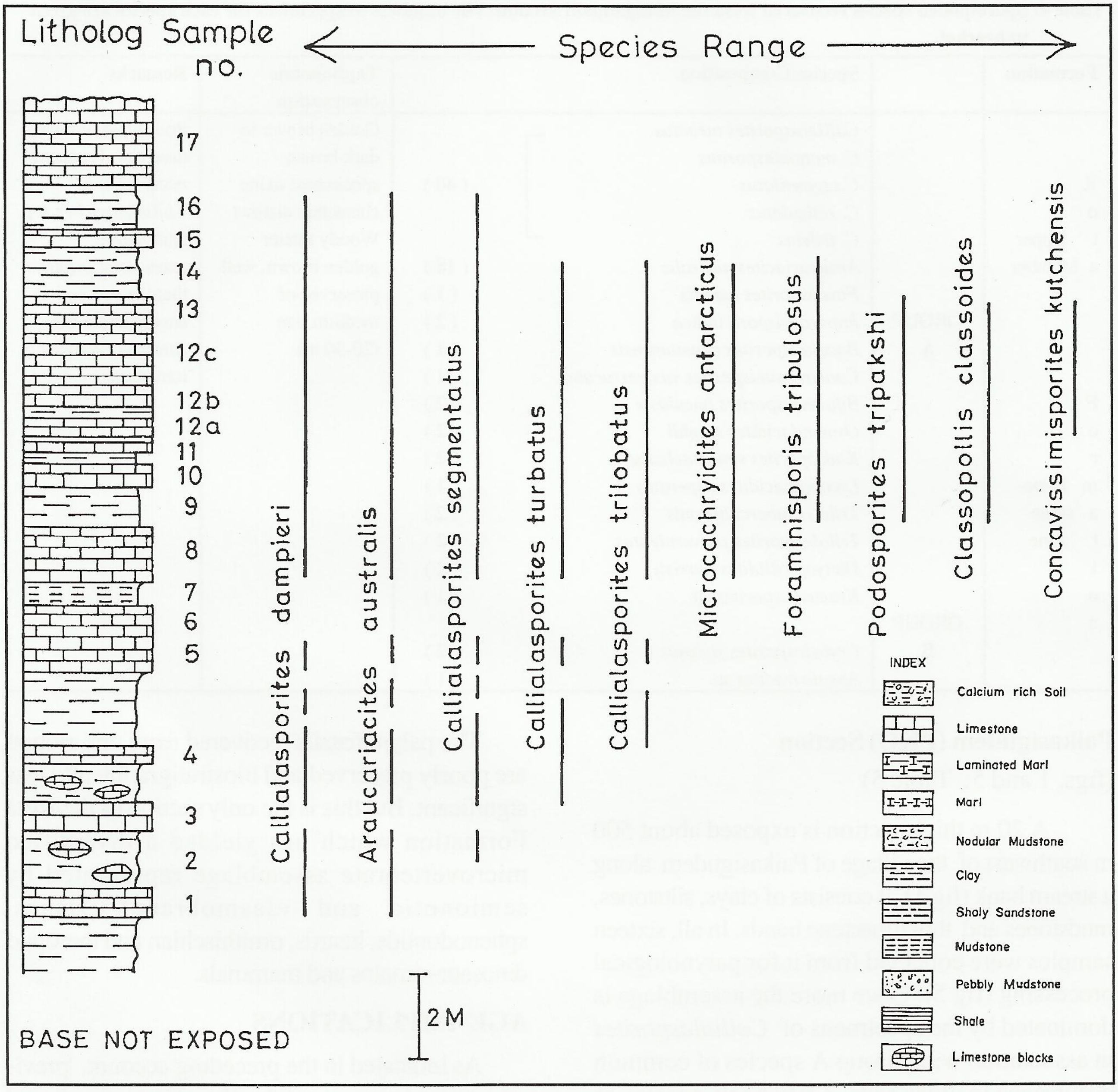

Fig.2. Lithological details and sample positions in the section exposed near the village of Metpali in Pranhita-Godavari Valley. Occurrences of characteristic spore-pollen species are given alongside the lithocolumn.

An integrated spore-pollen zonation has been presented recently by Vijaya (1999, 2000) for Jurassic and Lower Cretaceous successions on peninsular India. The first occurrence of *Callialasporites turbatus/dampieri* species marks the rocks of basal Jurassic, which is approximately Pliensbachian in age (in Burger, 1995; Vijaya, 2000). Gradually, this taxon is represented by 2-3 species and becomes more abundant in younger Early Jurassic deposits. The first appearance of *Contignisporites cooksoniae* is a Middle Jurassic marker (see Filatoff, 1975; Helby *et al.*, 1987).

The assemblage documented by Prabhakar (1989) from the Kota type section includes the dominant *Classopollis* group along with other pteridophytic spore species and gymnosperm pol-

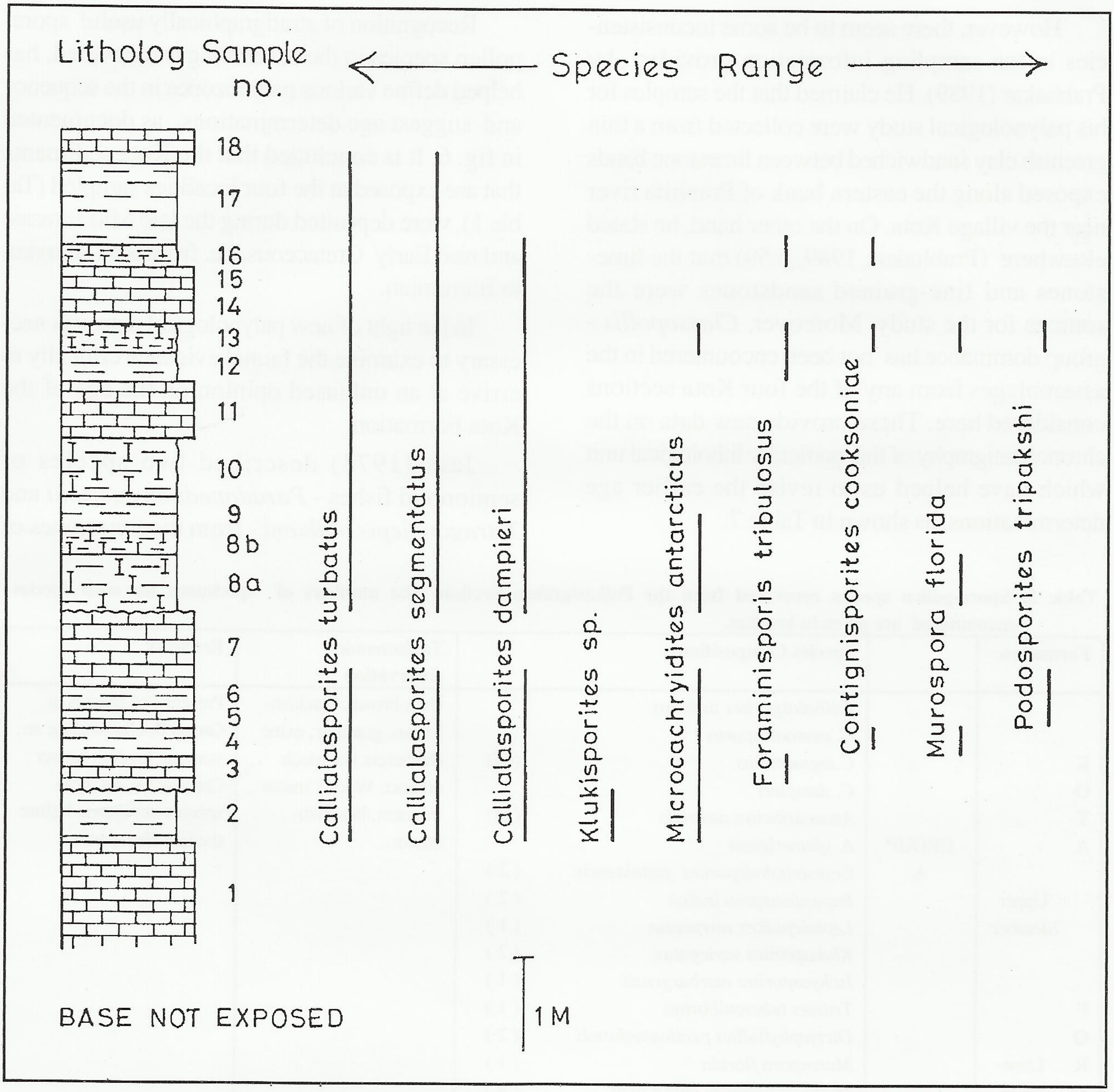

Fig.3. Lithological details and sample positions in the section exposed near the village of Kota, in the Pranhita-Godavari Valley. Occurrences of characteristic spore-pollen species are documented alongside the lithocolumn For key to lithologies, see fig 2.

len. The species of latter group are common in the Jurassic and Lower Cretaceous and hence, it does not contribute much to the age determination of the Kota sediments. The dominance of the *Classopollis* - group, (*Classopollis classoides, C. glandis, Gliscopollis pallidus* and *Granuloperculatipollis mudus*) has previously been noted as being characteristic for the Lower Jurassic Lathi Formation in Rajasthan (Srivastava, 1966), and the Lower Jurassic succession of the Kachchh Basin (Koshal, 1975). This is in contrast to the Lower Jurassic palynozones in Australian Mesozoic (Filatoff, 1975), which are characterised by having. *Araucariacites australis, Callialasporites turbatus, C. segmantatus,C. dampieri* as the established taxa.

However, there seem to be some inconsistencies in the sampling information provided by Prabhakar (1989). He claimed that the samples for his palynological study were collected from a thin greenish clay sandwiched between limestone bands exposed along the eastern bank of Pranhita river near the village Kota. On the other hand, he stated elsewhere (Prabhakar, 1989, p.59) that the limestones and fine-grained sandstones were the sources for the study. Moreover, *Classopollis* - group dominance has not been encountered in the assemblages from any of the four Kota sections considered here. These provide new data on the chronostratigraphy of this particular lithological unit which have helped us to revise the earlier age determinations, as shown in Table 7.

Recognition of stratigraphically useful spore-pollen species in the assemblages recovered, has helped define various palynozones in the sequence and suggest age determinations, as documented in fig. 6. It is concluded that the Kota sediments that are exposed at the four localities sampled (Table 1), were deposited during the late Mid Jurassic and mid Early Cretaceous, i.e. from the Callovian to Barremian.

In the light of new palynological data, it is necessary to examine the faunal evidence critically to arrive at an unbiased opinion on the age of the Kota Formation.

Jain (1973) described two species of semionotid fishes - *Paradapedium egertoni* and *Tetragonolepis oldhami* - from the limestones of

Table 5: Spore-pollen species recovered from the Paikasigudem Section. The numbers of specimens for each species encountered are given in bracket.

Formation		**Species Composition**		**Taphonomic observation**	**Remarks**
KOTA FORMATION		*Callialasporites turbatus*		Dark brown, blackish-brown, granular; exine characters not much distinct. Woody matter frequent, blackish-brown.	Presence of species in Group B, characterize an younger level in Lower Cretaceous. As these species not appear before the late Hauterivian.
		C. monoalasporus			
		C.segmentatus	(65)		
		C. dampieri			
		Araucariacites australis	(18)		
	GROUP A	*A. ghuneriensis*			
		Concavissimisporites penolaensis	(2)		
Upper Member		*Impardecispora indica*	(2)		
		Leptolepidites verrucatus	(1)		
		Klukisporites variegatus	(2)		
		Ischyosporites marburgensis	(1)		
		Triletes tuberculiformis	(1)		
		Dictyophyllidites pectinataeformis	(2)		
Lime-stone zone		*Murospora florida*	(1)		
		Microcachryidites antarcticus	(4)		
		Cicatricosisporites ludbrookii	(2)		
		Cooksonites rajmahalensis	(1)		
		C. variabilis	(3)		
		Cingurtiletes clavatus			
	GROUP B	*Coptpora micrograndulosa*	(6)		
		C. verrucosa			
		C. kutchensis			
		cf. *Triporoletes simplex*	(2)		
		Crybelosporites punctatus	(1)		
		cf. *Foraminisporis asymmetricus*	(1)		
		cf. *Appendicisporites* sp.	(1)		

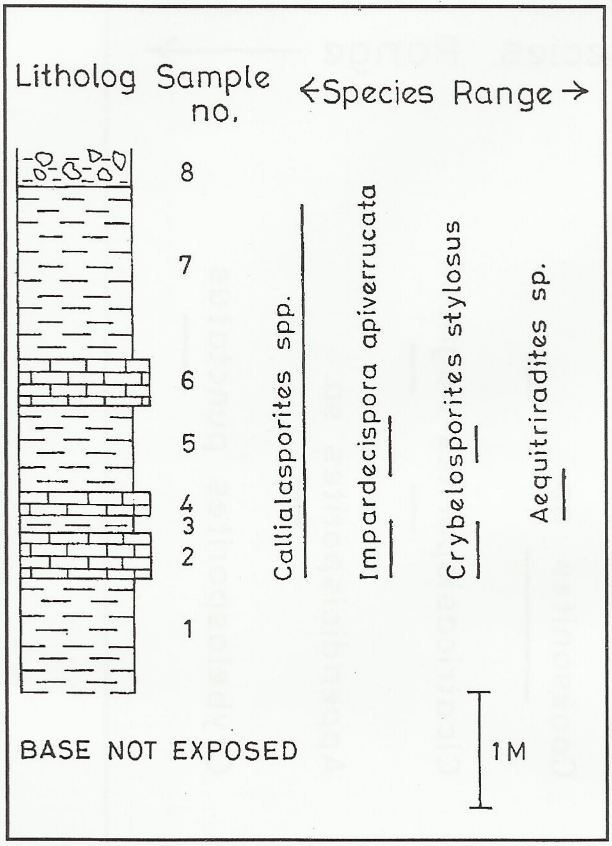

Fig.4. Lithological details and sample positions in the section exposed near the village of Manganpalli in the Pranhita-Godavari Valley. Occurrences of characteric spore-pollen species are documented alongside the lithocolumn. For key to lithology, see fig. 2.

the Kota Formation. He had erected a new genus *Paradapedium* with *D. egertoni* as type species and identified only one species of *Tetragonolepis* out of the three reported by Egerton (1851, 1854, 1878). Since *Tetragonolepis* is known from the Upper Liassic marine deposits of Europe, a more or less similar age has been suggested for the Kota Formation (Jain, 1973). In spite of the fact that *Paradapedium* is a new genus morphologically distinct from *Dapedium* (Lower to Upper Liassic of Europe), it was considered as an ecological substitute for *Dapedium* in Asia and accordingly, a stratigraphic range of Early to Late Liassic was proposed for this taxon (Jain, 1973). By comparison with *Lepidotes elvensis* known from the Upper Liassic of Europe, with which *L. deccanensis* of the Kota Formation shows some similarities, Jain

Table 6: List of spore-pollen species recognised in the four sections studied KT, MTP, MPL and PKG.

JURASSIC

Araucariacites australis Cookson, 1947
A. ghuneriensis Singh, Srivastava and Roy, 1964
Baculatisporites comaumensis (Cookson) Potonie, 1956
Biformaesporites baculosus Singh and Kumar, 1972
Callialasporites dampieri (Balme) Dev, 1961
C. monoalasporus Dev, 1961
C. segmentatus (Balme) Dev, 1961
C. triletus Singh, Srivastava and Roy, 1964
C. trilobatus (Balme), 1961
C. turbatus (Balme) Schulz, 1967
Ceratosporites equalis Cookson and Dettmann, 1958
Classopollis classoides Podock and Jansonius, 1961
Concavissimisporites subverrucosus Venkatachala, 1969
Contignisporites cooksoniae (Balme) Dettmann, 1963
C. multimuratus Dettmann, 1963
Densoisporites mesozoicus Singh, Srivastava and Roy, 1964
D. velatus Weyland and Kreiger emend. Krasnova, 1961
Dictyophyllidites harrisii Couper, 1958
Duplexisporites problematicus (Couper) Playford and Dettmann, 1965
Foraminisporis tribulosus Playford and Dettmann, 1965
Foveosporites canalis Balme, 1957
Impardecispora indica Venkatachala, 1969
I. apiverrucata (Couper) Venkatachala, Kar and Raza, 1969
Ischyosporites crateris Balme, 1957
Klukisporites foveolatus Pocock, 1962
K. venkatachalae Tripathi, Tiwari and Kumar, 1990
cf. *Kraeuselisporites linearis* (Cookson and Dettmann) Dettmann, 1963
Leptolepidites major Couper
Lycopodiacidites asperatus Dettmann, 1963
Matonisporites phlebopteroides Couper, 1958
Murospora florida (Balme) Pocock, 1961
Microcachryidites mesozoica Pocock, 1961
M. antarcticus Cookson, 1947
Osmundacidites singhii Ramanujam and Srisailam, 1974
Podocarpidites ornatus Pocock, 1962
Podosporites tripakshi Rao, 1947
Rugulatisporites sp.

CRETACEOUS

Aequitriradites sp.
cf. *Appendicisporites* sp
Araucariacites cooksonii Singh, Srivastava and Roy, 1964
Cicatricosisporites hughesii Dettmann, 1963
C. ludbrookii Dettmann, 1963
Cingutriletes clavus (Balme) Dettmann, 1963
Concavissimisporites penolaensis Dettmann, 1963
Cooksonites variabilis Pocock, 1962
C. rajmahalensis Tripathi, Tiwari and Kumar, 1990
Coptospora microgranulosa Venkatachala and Sharma, 1974
C. verrucosa Tripathi, Tiwari and Kumar, 1990
Crybelosporites stylosus Dettmann, 1963
C. punctatus Dettmann, 1963
cf. *Dictyotosporites complex* Cookson and Dettmann, 1968
Ischyosporites marburgensis de Jersey, 1963
Leptolepidites verrucatus Couper, 1953
Lycopodiacidites dettmannae Burger, 1980
Microfoveolatosporis atbertonensis Cookson, 1956
Triletes tuberculiformis Cookson, 1947
Trilobosporites purverulentus (Verbits.) Dettmann, 1963
Triporoletes simplex (Cookson and Dettmann) Playford, 1971

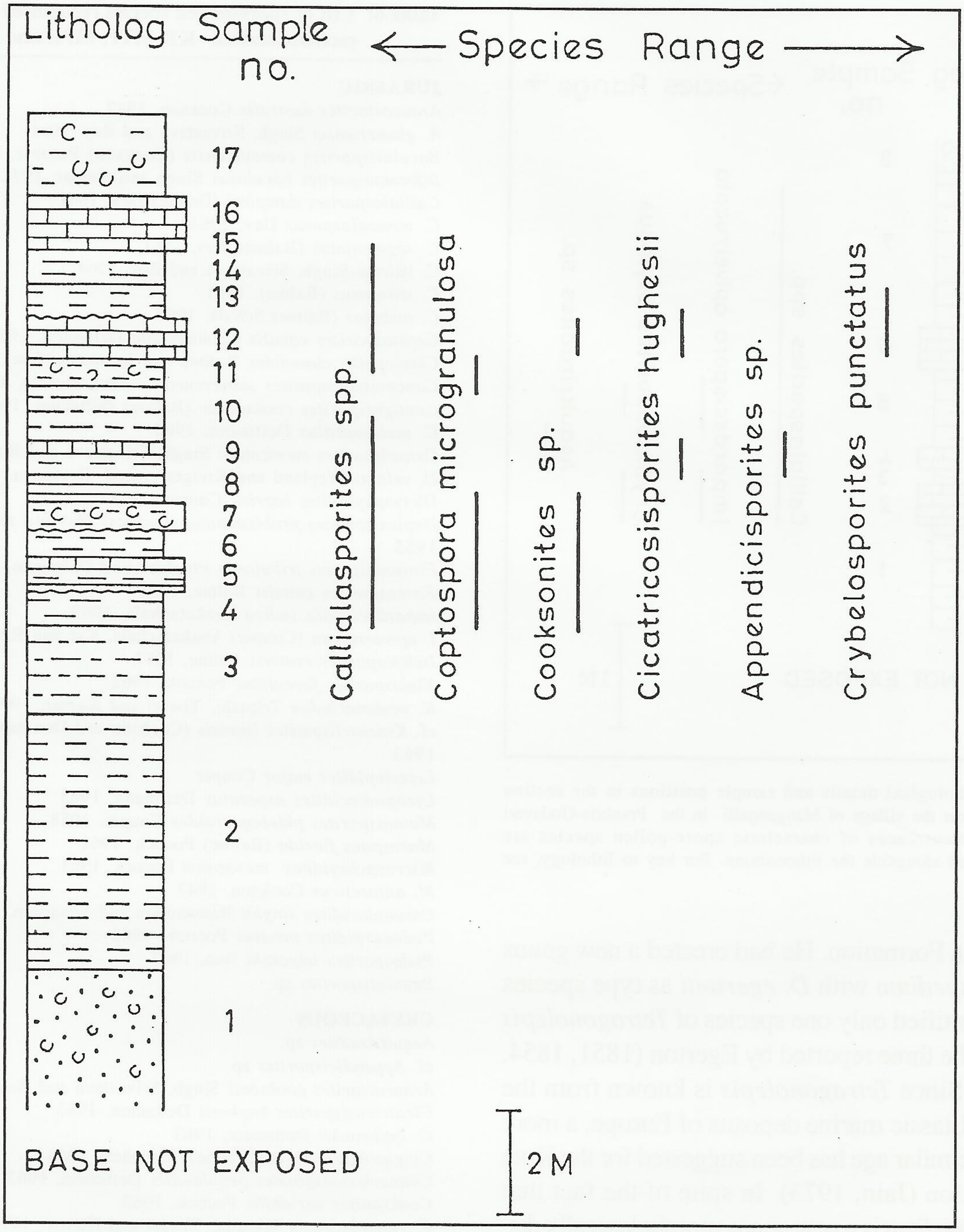

Fig.5. Lithological details and sample positions in the section exposed near the village of Paikasigudem, Pranhita-Godavari Valley. Occurrences of characteristic spore-pollen species are documented alongside the lithocolumn. For key to lithologics, see fig. 2.

(1983) favoured a similar age for the Kota Formation. Despite the similarities of *Indocoelacanthus robustus* to *Lualabaea,* a coelacanth fish known from the Middle to Upper Jurassic of Zaire, because of its occurrence in association with the semionotids led Jain (1974a) to conclude that this taxon is also of Early Jurassic age. Following these works on the Kota fishes, Yadagiri and Prasad (1977) described two new species of pholidophorid fishes - *Pholidophorus indicus* and

P. kingi - from the Kota Formation. Though the chronostratigraphic range of pholidophorid fishes extended from Triassic to Upper Jurassic and the fossils belong to new species, the authors influenced by the earlier age assignments favoured an Early Jurassic age for the Kota Formation. Further, Jain (1974b) reported a flying reptile *Campylognathoides indicus* from the Kota limestone and as this genus occurs in the Upper Liassic of Holzmaden, Germany, this has been shown as an evidence in favour of Lower Jurassic age. It should be noted here that pterosaurs are not as such reliable for age determinations.

Govindan (1975) described an ostracode assemblage comprising *Darwinula* cf. *D. sarytirmenensis,* ? *Limnocythere* sp. A, and *Timiriasevia digitalis* from the limestone and intercalated clays of the Kota Formation exposed at Metpalli, Kanchelli, Daroghapalli, Akkalapalli, and Potepalli. Of these taxa, *Timiriasevia digitalis* is a new species not known from any other Jurassic sections in the world and the identification of *Limnocythere* is not definitive. According to Govindan (1975), *D. sarytirmenensis* was originally documented from the Middle Jurassic Mangishlaka peninsula in Russia, *Limnocythere* extends from Early Jurassic to Recent, and *Timiriasevia* ranges from Middle Jurassic to Palaeocene. It is exclusively on the basis of *Darwinula* cf. *D. sarytirmenensis* and *Timiriasevia digitalis,* Govindan (1975) favoured a Middle Jurassic age for the Kota Formation. Subsequently, *D. sarytirmenensis* has also been documented from the upper Middle Jurassic to Upper Jurassic deposits of China (Meizhen, 1984; Hao, Su and Li, 1983). Recently, Kietzke and Lucas (1994) have reported the same species from the Lower Jurassic Kayenta Formation. Therefore, the stratigraphic range of *D. sarytirmenensis* extends from Early Jurassic to Late Jurassic.

Following Govindan's (1975) work, Misra and Satsangi (1979) documented an ostracode assemblage represented by *Darwinula* cf. *D. sarytirmenensis, D. kingi, Darwinula* sp. 1, *Darwinula* sp. 2, ?*Stenocypris* sp., *Cypridea* sp., *Eucandona* sp., *Clinocypris* sp., ?*Limnocythere* sp., and *Timiriasevia digitalis* from the limestones of the Kota type section near Kota village and Kota clays near Vemanapalli. These authors have not discussed the stratigraphic range of the taxa other than those described by Govindan (1975) and accepted the Middle Jurassic age suggested by Govindan (1975). More recently, Mallikarjuna, McKenzie and Prasad. (personal communication) carried out a detailed study of ostracodes from different sections of the Kota Formation. They have accepted Govindan's (1975) contention that darwinulids, being long ranging forms, are not well suited for age determination. But they have also recovered a few species of candonids (*Candona* cf. *C. bagmodica, Candona* cf. *C. altanulaensis, Candona* cf. *C. henaensis, C. stirlingensis*) from the Kota ostracode assemblage. Based on these candonids, they suggested a Late Jurassic to Early Cretaceous age for the Kota Formation..

Feist *et al.* (1991) reported a charophyte taxon *Aclistochara* cf. *A. jonesi* (Family Characeae) from the limestone zone of the Kota Formation exposed near Paikasigudem and Vemanapalli. According to these authors, the Indian specimens are closely comparable to *A. jonesi* known from the Upper Jurassic to Early Cretaceous of Colorado and Wyoming, USA (Peck, 1957) and China (Liu, 1982). Besides, *A. bransoni* another species of *Aclistochara* is also known from the Upper Jurassic Morrison Formation, South Dakota, USA (Feist *et al.*, 1991). Despite this, Feist *et al.* (1991) chose to follow the long established Early Jurassic age based on semionotid fishes and flying reptiles and extended the lower range of the family Characeae to Lower Jurassic from Upper Jurassic. Bhattacharya *et al.* (1994) described a second charophyte taxon *Praechara symmetrica* from the limestone and calcareous marl underlying the limestone beds of

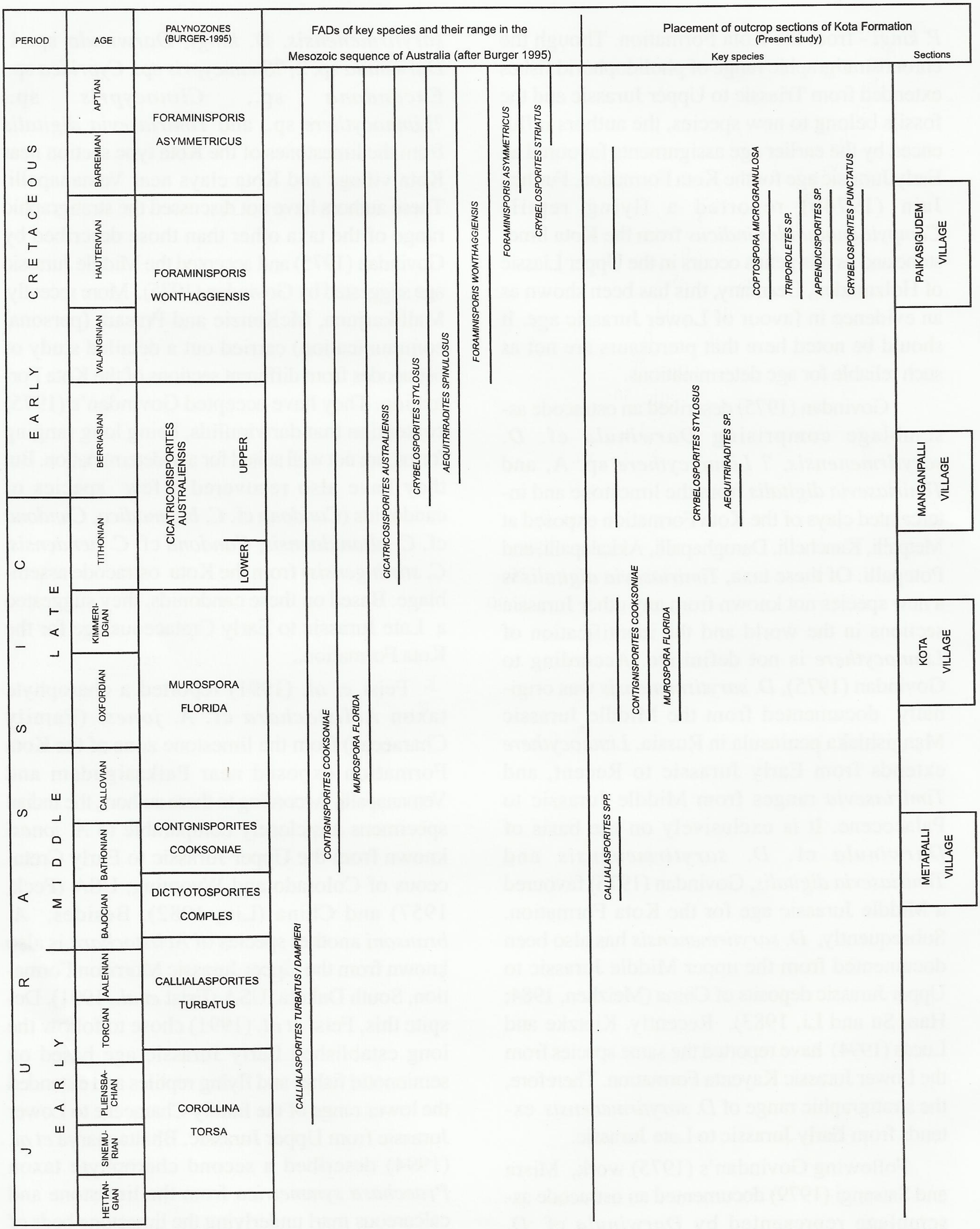

Fig.6. Biostratigraphic location of the four sections investigated within the Kota Formation in the Pranhita-Godavari Valley, and their relative age correlation within the palynozonation scheme of the Australian Mesozoic sequence (after Burger, 1995; Vijaya 2000).

Table 7: Biostratigraphic placement of the outcrop sections of the Kota Formation, investigated on the basis of the occurrences of spore-pollen biostratigraphic markers (see in Vijaya, 1999, 2000).

Era	Period	Formation	Section	Lithology	Characteristic species	Age Assessment
MESOZOIC	LOWER CRETACEOUS	KOTA FORMATION / UPPER MEMBER / LIMESTONE ZONE	Paikasigudem village 20m thick	Bedded Limestones,	*Crybelosporites punctatus* *Appendicisporites sp.* *Triporoletes simplex* *Coptospora microgranulosa*	Early Barremian to Late Hauterivian
			Manganpalli village 4.5m thick	Calcareous clays and mudstones	*Crybelosporites stylosus* *Aequitriratites sp.*	Early Berriasian to Latest Tithonian
	JURASSIC		Kota village 10m thick		*Murospora florida* *Contignisporites cooksoniae*	Kimmeridgian to Callovian
			Metpalli village 19 m thick		Predominantly *Callialasporites* spp in non-diversified assemblage	

Kota Formation and favoured a Liassic age. But these authors provided no locality map or information on the fossil-yielding site. They argued that the partial closure of gyrogonite apex by coming together of five spiral cells was achieved in *Praechara* which has evolved from Porocharaceae in the Liassic and is less evolved than *Aclistochara* reported from the same formation.

Recently, triconodont and morgaucodontid mammals have been recorded from the Paikasigudem section (Datta, 1981; Yadagiri, 1984, 1985; Prasad and Manhas, 1997, 2001, *in press*). The triconodonts are represented by a new species of *Dyskritodon* (Prasad and Manhas, 2001, *in press*) and *Paikasigudodon yadagiri* n. comb. Prasad & Manhas, 1997, whereas morganucodontid is known by *Indotherium pranhitai* Yadagiri, 1984. Among these, *Dyskritodon* is very important from chronostratigraphic point of view. *Dyskritodon* is very similar at generic level to *Dyskritodon amazighi* described from the Early Cretaceous (?Berriasian) Anoual locality of Morocco (Sigogneau-Russell, 1995). If we accept the Late Liassic age for the Kota Formation, a gap of about 45-50 m.y. exists between the deposition of the two deposits. But it is apparent from the Mesozoic fossil record that no mammalian genus has survived such a long period of time. This casts some doubt on the age assignment of these widely separated sites. One can think of two possibilities. Either the Kota Formation is younger than the well entrenched Late Liassic age or the Anoul site is older than Early Cretaceous. The latter proposition can be rejected as the Anoual mammal-bearing level has been more precisely dated on the basis of age-diagnostic nannofossils than the Kota Formation. Therefore, an younger age for the Kota Formation appears to be more probable. The presence of mammalian teeth (*Indotherium pranhitai)* with some affinities to morganucodontids, which have been documented until now from Upper Triassic to Middle Jurassic deposits of South Africa, Europe, and China, further compounded the problem.

More recently, first docodont mammals of Laurasian affinity have been recovered from the Kota microvertebrate assemblage (work in progress). These forms, though exhibit many morphological similaritties to those of Late Jurassic *Haldanodon* of Portugal (Krusat, 1980), appear to represent an evolutionary grade more primitive than *Haldanodon*. Thus, the Kota mammalian assemblage is an admixture of primitive (*Indotherium pranhitai* and docodont mammals) and derived (*Dyskritodon*) forms. This has also been reflected by the charophytes. The Kota charophyte taxon *Aclistochara* cf. *A. jonesi* (Family Characeae, Feist *et al.*, 1991) has been considered as a derived form with respect to *Praechara symmetrica* (Family Porocharaceae, Bhattacharya *et al.*, 1994). *Aclistochara* has originally been described from the Upper Jurassic to Lower Cretaceous deposits of North America and China (Feist *et al.*, 1991), whereas *Praechara* has been considered as Liassic in age (Bhattacharya *et al.*, 1994). This temporal mixing of derived taxa with primitive ones can be explained either by lowering the lower stratigraphic range of derived forms or by raising the upper stratigraphic range of primitive forms. The first proposition appears less plausible at our present state of knowledge. For example, the lower range of *Dyskritodon*, originally known from the Early Cretaceous of Morocco has to be extended down at least by 45-50 m.y. From the known evolutionary rates of early mammals, this seems unlikely. In view of this, the second proposition deserves some serious consideration.

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