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Spores-Pollen Assemblage from the Yunoki Formation of the Monobegawa Group, South-West Japan

KOZAI Takeshi* and VIJAYA**

(Keywords: Palynomorphs, Yunoki Formation, Lower Cretaceous, Outer Zone of SW Japan, Integrated biostratigraphy)

1. Introduction

The Yunoki Formation represents the middle part of the Monobegawa Group in the central part of the Outer Zone of South-West Japan (Fig. 1). The Yunoki Formation (Fig. 2) has increasingly raised the interest for biostratigraphic examinations since the study of its fauna (Kozai *et al*., 2005). This led to the present analysis of its spores and pollen.

Early Cretaceous megafloras are found mainly in the Tetori and Monobegawa groups (Yabe, 1913; Oishi, 1940; Kimura and Hirata, 1975). The Yunoki flora is of the Ryoseki-type that spreads over south-east Asia, differing from the Tetori-type that extends to north-east Asia (Kimura, 1987). For the first time, a diversified spores and pollen assemblage is found in the Outer Zone of South-West Japan. The diverse spores and pollen association in the Yunoki Formation contributes to an integrated biostratigraphy of the Monobegawa Group.

2. Geological Setting and Age

The Median Tectonic Line (MTL) subdivides S-W Japan into the Outer Zone and the Inner Zone. In the Outer Zone, three groups, the Monobegawa, Nankai and Takegatani, comprise Early Cretaceous successions. Among these, the Monobegawa Group and equivalents extends over Kyushu, Shikoku, the Kii peninsula and the Sanchu area of central Honshu.

The Monobegawa Group extends in the Monobe and Tokushima areas of Shikoku (Fig. 1). In the Monobe area of central Shikoku, the Monobegawa Group is subdivided into the Ryoseki, Monobe, Yunoki and Hibihara formations in ascending order (Tashiro and Kozai, 1984). The Ryoseki Formation unconformably overlies the Permian Accretionary Complex (PAC).

As the Monobegawa Group consists of several depositional facies, each of which is characterized by an upward thinning succession, three different non-marine bivalve faunas characterize the group (Kozai and Ishida, 2003; Kozai *et al*., 2005). The Hauterivian Ryoseki Formation encompasses the Tatsukawa fauna that contains many brackish water and freshwater molluscs. The Barremian Monobe Formation yields abundant marine molluscs and radiolarian assemblages. The Late Barremian Yunoki Formation yields brackish water bivalves (Tanaka *et al*., 1984) and the Aptian to Albian Hibihara Formation contains abundant brackish water bivalves, marine molluscs and ammonites. These local late Barremian to early Aptian marine and brackish-marine intercalations were precursors of the main Aptian transgression.

3. Sample locality

The Yunoki Formation is about 450 m thick. The sequence consists in its lower part of grey sand-

*Laboratory of Geosciences, Naruto University of Education, Naruto-City, Tokushima 772-8502, Japan
**Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow-226007, India

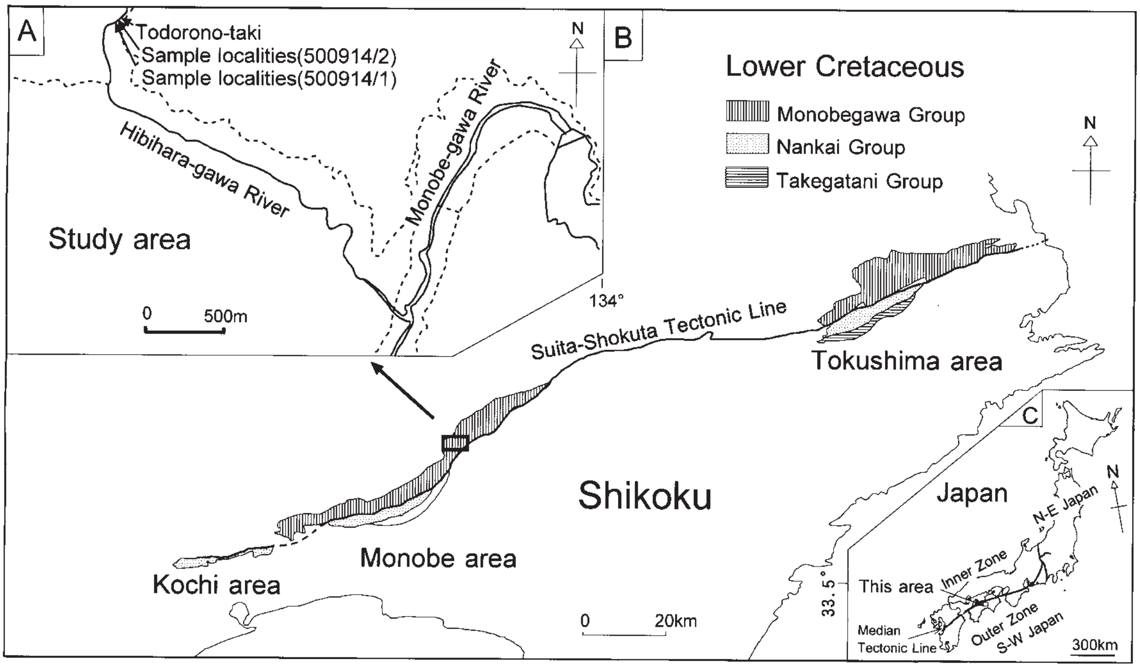

Fig. 1 Distribution of Lower Cretaceous sediments in the Monobe area, Japan, showing the study area and location of rock samples for spores-pollen study (after Kozai *et al.*, 2005).

stone, thin black mudstone, dark grey muddy sandstone, pebbly sandstone and conglomerate. The upper part consists of mudstone, some intercalated acidic tuff and alternating beds of mudstone and fine-grained sandstone.

At the locality of Todorano-taki along the Hibihara-gawa River in the Monobe area of central Shikoku, we collected samples from six units in the middle part of the Yunoki Formation (Fig. 3). Unit A consists of cross-bedded channel-fill suggesting a braided river environment. Unit B, containing gastropods and root traces in carbonaceous mudstone is interpreted as flood plain deposits. In Unit C, wave-rippled cross laminae with mud drapes in sandstone beds containing plant fragments, suggest tidal flat deposition. Unit D (our locality 500914/1) consists of carbonaceous mudstone (samples 1 to 5), silty mudstone (samples 6 and 7) and sandstone with coal seams. This unit is interpreted as flood plain deposits that gradually pass into Unit E which appears to be tidal flat deposits. The last Unit F (our locality 500914/2) consists of carbonaceous mudstone (samples 1 to 7) and is interpreted as flood plain deposits (Walker and Cant, 1984).

4. Palynological Results

In the present study, the fourteen samples from the middle part of the Yunoki Formation (Fig. 3) were processed for their spores and pollen. These samples were crushed, and treated with HCl and HF according to the standard palynological technique, taking care not to destroy specimens. The organic matter was treated with mild alkali (NaOH) in order to eliminate humous. Polyvinyl was used as mounting medium. The slides are stored in the Museum at the Birbal Sahni Institute of Palaeobotany.

Samples 500914-1/1-4 and 6 (in Unit D), and 500914-2/1-4 (in Unit F), proved to be almost barren of spores and pollen, while the other samples 1/5 and 7, and 2/5-7, next to re-worked Permian and a few Triassic striate bisaccate pollen, yielded a spores and pollen assemblage that provides data for stratigraphic correlation. Check-lists of taxa and relative abundance are given (Table 1 and 2). Although generally poorly preserved, most characteristic taxa are illustrated in Figs. 4 and 5.

The Lower Cretaceous palynoflora exhibits a high degree of species diversity. The assemblage is characterized by an overwhelming abundance of spores (apiculate, cingulate and costate).

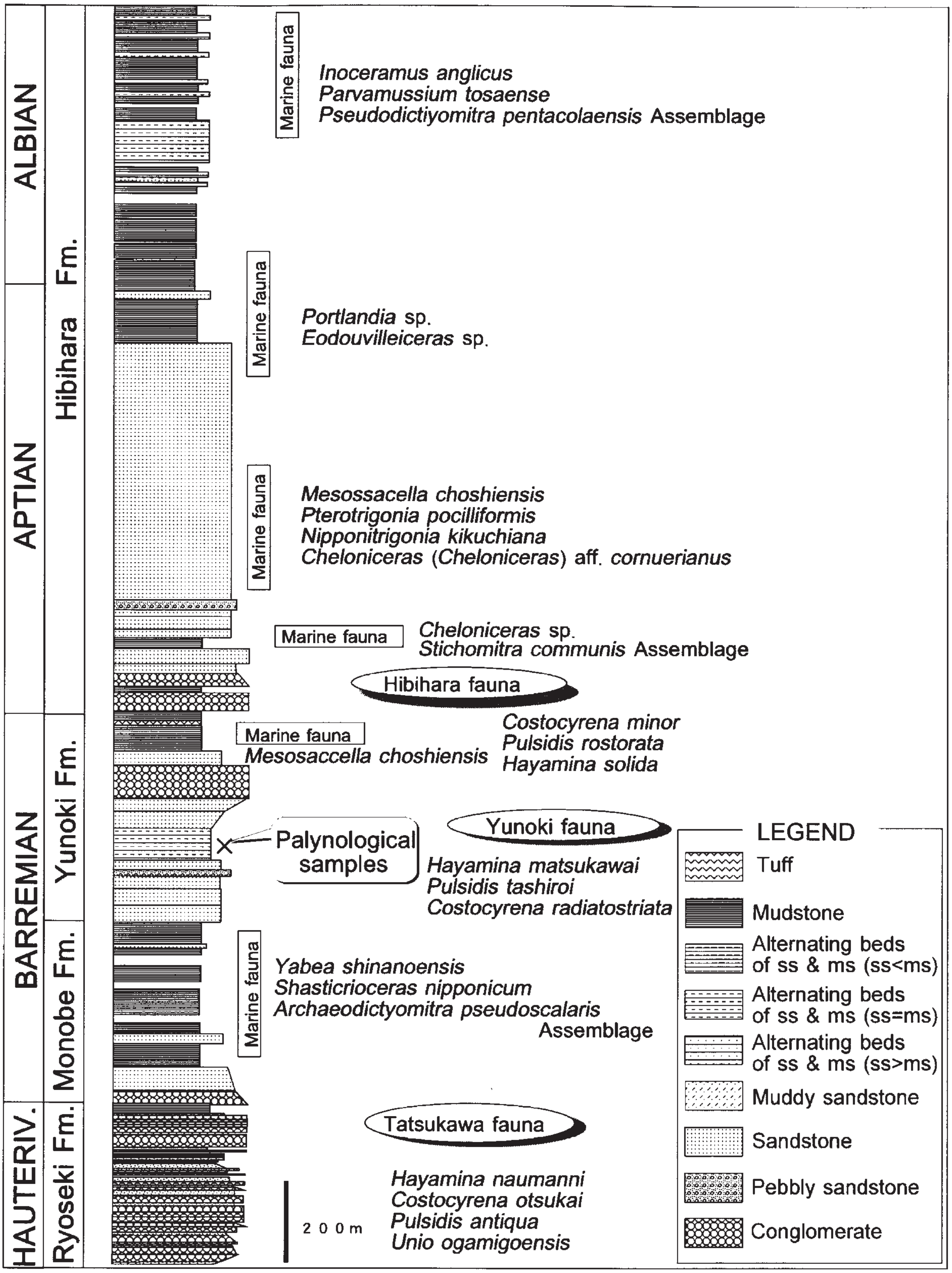

Fig. 2 Lithological column of the Monobegawa Group to illustrate the stratigraphic horizons of faunal occurrences and palynological samples.

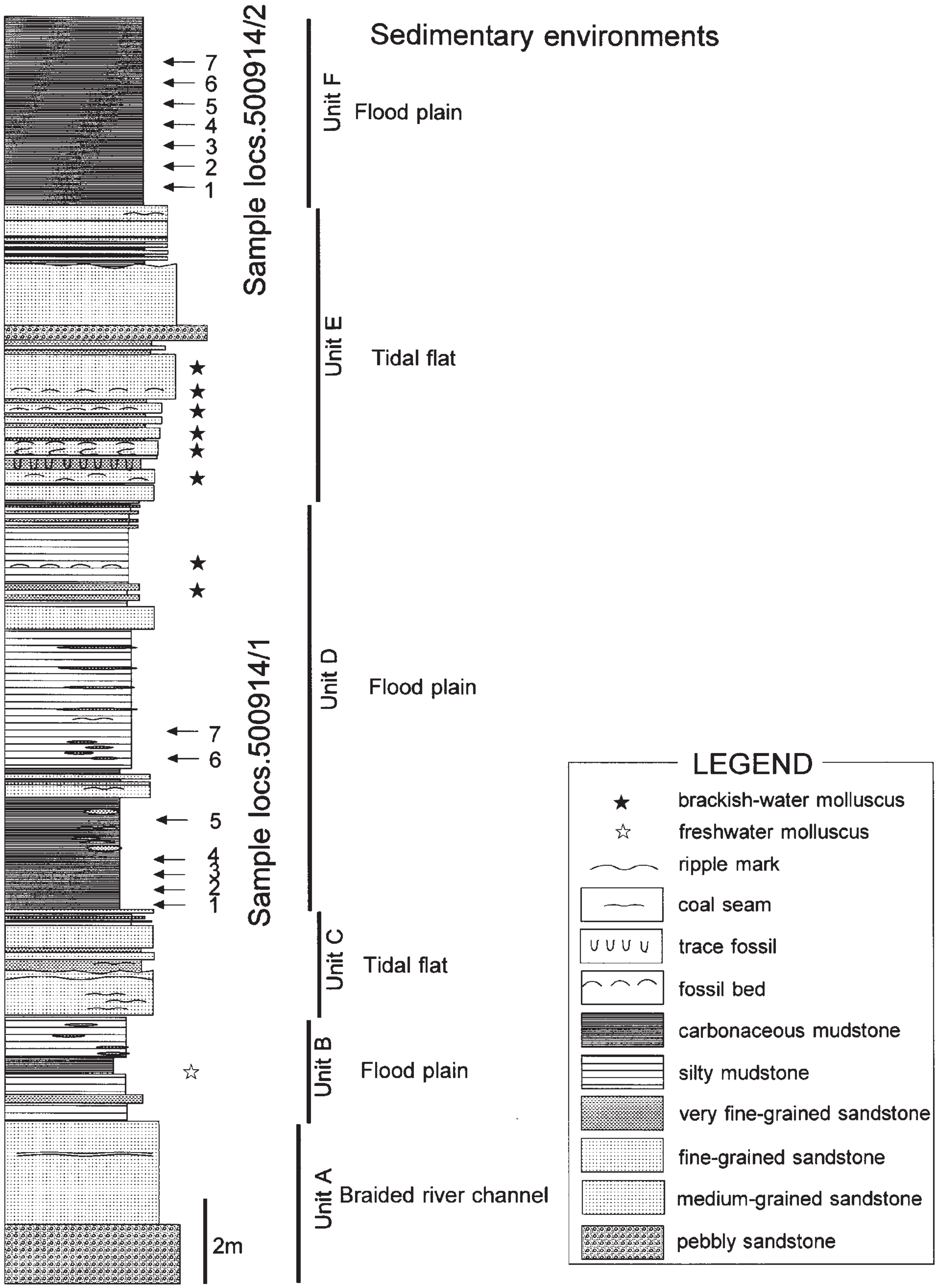

Fig. 3 Lithological column of the Yunoki Formation showing sampled horizons for the present study (after Kozai *et al*., 2005).

Table 1. Check list of spores-pollen species identified from the Yunoki Formation, South-West Japan

Aequitriradites verrucosus	Cookson & Dettmann 1961
Alete spores	Cookson & Dettmann 1961
Alsophilidites densus	Singh *et al*. 1964
Antulsporites cf. *distaverrucosus*	(Brenner) Archangelsky & Gamerro 1966
Appendicisporites jansonii	Pocock 1962
Appendicisporites problematicus	(Burger) Singh 1971
Appendicisporites spinosus	Pocock 1962
Araucariacites australis	Cookson 1947
Araucariacites ghuneriensis	Singh *et al*. 1964
Biretisporites potoniaei	Delcourt & Sprumont 1955
Boseisporites insignitus	Venkatachala 1969
Callialasporites monoalasporus	Dev 1961
Callialasporites triletus	Singh *et al*. 1964
Callialasporites trilobatus	(Balme) Dev 1961
Ceratosporites couliensis	Srivastava 1972
Cicatricosisporites annulatus	Archangelsky & Camerro 1965
Cicatricosisporites hallei	Delcourt & Sprumont 1953
Cicatricosisporites hughesi	Dettmann 1963
Cicatricosisporites pseudotripartitus	(Bolkhovitina) Dettmann 1963
Cingulizonates rhaeticus	Schulz 1967
Cingutriletes clavas	(Balme) Dettmann 1963
Classopollis classoides	Pflug emend. Pocock & Jansonius 1961
Concavisporites juriensis	Balme 1957
Concavissimisporites penolaensis	Dettmann 1963
Concavissimisporites verrucosus	Delcourt & Sprumont 1955
Contignisporites crenatus	Varma & Ramanujam 1984
Contignisporites multimuratus	Dettmann 1963
Cooksonites variabilis	Pocock 1962
Coptospora verrucosa	Tripathi *et al*., 1990
Couperisporites complexus	(Couper) Pocock 1962
Couperisporites tabulatus	Dettmann 1963
Crybelosporites striatus	(Cookson & Dettmann) Dettmann 1963
Crybelosporites stylosus	Dettmann 1963
Densoisporites velatus	Welyland & Krieger emend. Krasnova 1961
Dictyophyllidites sp.	Couper 1958
Dictyotosporites filosus	Dettmann 1963
Dictyotriletes pseudoreticulatus	(Couper) Pocock 1962
Echinatisporis varispinosus	(Pocock) Srivastava 1975
Ephedripites multicostatus	Brenner 1963
Ephedripites virginiaensis	Brenner 1963
Foraminisporis asymmetricus	(Cookson & Dettmann) Dettmann 1963
Foraminisporis wonthaggiensis	(Cookson & Dettmann) Dettmann 1963
Gabonisporis bacarecumulus	Srivastava 1972
Gabonisporis labyrinthus	Srivastava 1972
Gabonisporis papillosus	Tripathi *et al*. 1990
Gleicheniidites circinidites	(Cookson) Dettmann 1963
Gleicheniidites senonicus	Ross 1949
Januasporites reticularis	Pocock 1962
Klukisporites venkatachalae	Tripathi *et al*. 1990
Kraeuselisporites cf. *majus*	(Cookson & Dettman) Dettmann 1963
Leptolepidites major	Couper 1953
Leptolepidites rimatus	Tripathi *et al*. 1990
Leptolepidites verrucatus	Couper 1953
Lycopodiacidites dettmannae	Burger 1980
Matonisporites cooksoni	Dettmann 1963
Microcachryidites antarcticus	Cookson 1947
Neoraistrickia truncatus	(Cookson) Potonie 1956
Pilosisporites grandis	Dettmann 1963
Pilosisporites trichopapillosus	(Thiergart) Brenner 1963
Pilosisporites verus	Delcourt & Sprumont 1955
Podocarpidites ellipticus	Cookson 1947
Podocarpidites multesimus	(Bolkhovitina) Pocock 1962
Podosporites microsaccatus	(Cooper) Dettmann 1963

Polycingulatisporites radiatus	Singh 1971
Polycingulatisporites reduncus	(Bolkhovitina) Playford & Dettmann 1965
Ruffordiaspora australiensis	(Cookson) Dettmann & Cliflord 1992
Ruffordiaspora ludbrookiae	(Dettmann) Dettmann & Cliflord 1992
Santhalisporites bulbosus	Tripathi *et al*. 1990
Schizosporis rugulatus	Cookson & Dettmann 1959
Taurocusporites sp.	Singh 1964
Trilobosporites apiverrucatus	Couper 1958
Trilobosporites marylandensis	Brenner 1963
Triporoletes radiatus	(Dettman) Playford 1971
Triporoletes reticulatus	(Pocock) Playford 1971
Verrucosisporites kazigaonensis	Tripathi *et al*. 1990

Within the interval from 500914-1/5 and 7 to 500194-2/5-7, species of *Aequitriradites, Alsophilidites, Appendicisporites, Concavissimisporites, Couperisporites, Foraminisporis, Gabonisporis, Gleicheniidites, Pilosisporites* and *Trilobosporites* are present. Although the numbers of the specimens are not large (Table 2), the assemblage is morphologically diverse and includes *Aequitriradites tilchensis, Antulsporites distaverrucosus, Cicatricosisporites augustus, C. hallei, Coptospora verrucata, Cooksonites rajmahalensis, Crybelosporites berberioides, C. punctatus, C. striatus, Cyclosporites hughesii, Gabonisporis papillosus, Januasporites* spp., *Lycopodiacidites rimatus, Pilosisporites* spp., *Santhalisporites* spp. and *Trilobosporites trioreticulatus* (Table 1). These species are consistently present in the studied strata, and contribute to the age determination of this assemblage. Here the rareness of gymnospermous pollen (e.g. *Araucariacites, Podocarpidites, Callialasporites* etc.) is notable.

4.1. Palynostratigraphy

A steady change is observed among the spores and pollen assemblages of the Neocomian (Berriasian to Hauterivian) (Helby *et al*., 1987). The assemblage described in this sequence contains *Appendicisporites* spp., *Crybelosporites striatus, C. punctatus, Couperisporites* spp., *Foraminisporis asymmetricus* and *Pilosisporites* spp. These are index species that are characteristic for younger Early Cretaceous (Burger, 1990; Vijaya, 1999). The proposed palynozonation is based on First Appearance Datum (FAD) of index species, each on its own sufficient for palinozonal identification. Their worldwide coverage is based on references from both north and southern hemispheres: India (Varma and Ramanujam, 1984; Singh and Venkatachala, 1988; Tiwari and Tripathi, 1995; Tripathi *et al*., 1990; Vijaya, 1999, 2004); Australia (Helby *et al*., 1987; Burger, 1980, 1990, 1995; Dettmann, 1963; Dettmann and Playford, 1969; Dettmann *et al*., 1992; McLoughlin *et al*., 1995); Europe and North America (Couper, 1958; Pocock, 1962; Singh, 1964, 1971; Phillips and Felix, 1971; Srivastava, 1972; Arias and Doubinger, 1980; Schrank, 1994) and China (Li and Liu, 1994; Liu, 2000; Wan *et al*., 2002; Huang and Long, 2008).

With reference to the stratigraphic ranges mentioned herein for Barremian to Aptian, the stratigraphically important species of the spores are recovered in the studied horizons of the Yunoki Formation (Fig. 3). The following three groups of species have been identified in the assemblage (Table 3):

Group I: Forms that range from the earliest Berriasian to the Aptian. Their assemblage encompasses taxa common within the lowermost Cretaceous.

Group II: The FAD of *Foraminisporis wonthaggiensis* corresponds to the maximum diversity of *Cicatricosisporites, Ruffordiaspora* and many other sculptured trilete spores. The assemblage is representative for the Valanginian-Hauterivian transition, occasionally extending to the Aptian.

Group III: The occurrences of *Appendicisporites* spp., *Couperisporites* spp., *Crybelosporites* spp., *Gabonisporis* spp., *Pilosisporites* spp. and *Santhalisporites* spp. confer Barremian to Aptian ages (Burger, 1990; Tiwari and Tripathi, 1995; Vijaya, 2004).

4.2. Comparision with other palynoassemblages

Lower Cretaceous palynoassemblages are on record from various parts of the globe, revealing the two contrastive northern *Cerebropollenites* and southern *Schizaeoisporites* palynofloral provinces (Batten and Li, 1987; Herngreen and Chlonova, 1981; Srivastava, 1994; Nichols, 2003; Liu, 2000; Wan *et al*., 2002; Huang and Long, 2008).

Recently, Umetsu and Sato (2007) have reported Early Cretaceous palynoassemblages from the Miyako Group in North-East Japan and from the Tetori Group in the Inner Zone of South-West Japan. There is no obvious difference between the assemblages from these two localities except for the relative abundance of fern spores versus gymnosperm pollen that might be related to near shore sedimentary environment. The present Yunoki spores-pollen assemblage is characterized by the abundance of fern spores (Tables 1 & 3).

The dominance of pteridophytic spores in the assemblage supports comparison with the assemblage of the Tetori Group. The fern spores *Appendicisporites, Cicatricosisporites, Cyathidites, Klukisporites, Osmundacidites* and *Schizaeoisporites*, as well as bisaccate gymnosperm pollen occur in northeast and central Ja-

Table 2. Relative abundance of spore-pollen species in the studied section of the Yunoki Formation. Present=P (1), Low=L (2), Moderate=M (3-5), Abundant=A (more than 5 specimens)

Sample No. / Spore - Pollen	50914/2				50914/1		
	7	6	5	4-1	7	5	6, 4-1
Aequitriradites spp.	P	P	L		P	L	
Alete spores	P		L		P		
Alsophilidites densus	P		L		P	L	
Appendicisporites jansonii	L	P			L	L	
Appendicisporites spp.	L		P		P	P	
Araucariacites ghuneriensis	L	M	L		L	M	
Boseisporites insignitus		L			L	P	
Callialasporites monoalasporus	L		P		M	P	
Callialasporites triletus	P		L		P	L	
Callialasporites trilobatus	L	M	L		M	L	
Ceratosporites couliensis		P			P		
Cicatricasisporites spp.	P	P	L		P	L	
Cingulizonates rhaeticus	L		L		P	M	
Cingutriletes clavas	L				L		
Classopollis classoides	L		P		L		
Concavisporites juriensis	L	L	L			M	
Concavissimisporites spp.	L	P	L			M	
Contignisporites spp.	P	L	L		L	L	
Cooksonites variabilis	M	L	L		L	L	
Coptospora verrucosa	L	P	P		L	P	
Couperisporites variabilis	P	L	L		M	A	
Crybelosporites spp.	P	P	L		L	P	
Densoisporites velatus	P		P		P	P	
Dictyophylidites sp.		P	L		L	M	
Dictyotosporites filosus	P		P		P		
Dictyotriletes psuedoreticulatus		P	P		P		
Foraminisporis asymmetricus	P		L		L	L	
Foraminisporis wonthaggiensis	L		P		P	L	
Gabonisporis spp.	P		M		P	M	
Gleicheniidites spp.			L			L	
Januasporites reticulatus		L	P			L	
Klukisporites venkatachalae		P	L		L		
Kraeuselisporites cf. *majus*	L		L		L	M	
Leptolepidites rimatus	M		P		L		
Lycopodiacidites dettmannae	L	P			P		
Microcachryidites antarcticus	L	L			M	L	
Pilosisporites spp.	P	P	L		M	P	
Podocarpidites spp.	P	M	M		M	M	
Podosporites microsaccatus	P		P		P	P	
Polycingulatisporites spp.		P	L		L	P	
Ruffordiaspora spp.	P	P	L		P	L	
Santhalisporites bulbosus	L	P	M		P	M	
Trilobosporites spp.	L	P	L		L	L	
Triporoletes spp.	P	P	P		L	P	
Verrucosisporites kazigaonensis			P			P	

pan (Umetsu and Sato, 2007). While the major taxa remain similar, the species composition might differ and no angiosperm pollen is on record in the Yunoki flora.

In the palynoflora of Japan (Umetsu and Sato, 2007), northeastern and central China (Li and Liu, 1994), *Classopollis* is a major Berriasian component, a taxon that on the Indian peninsula occurs mainly in the Lower Jurassic deposits. Excluding the record of *Classopollis*, only costate spore *Cicatricosisporites* and bisaccate gymnospermous pollen remain to be accounted for. A transitional Early Cretaceous palynofloral province between *Cerebropollenites* and *Schizaeoisporites* provinces is suggested to exist (Umetsu and Sato, 2007).

Summing up, the studied spores and pollen assemblage contains an admixture of many taxa, which are diagnostic for both the northern Gondwanan and Asian regions during the Barremian - Aptian time-span (Table 3). Hence, a correlation with the *Foraminisporis asymmetricus* Palynozone in the Lower Cretaceous of Australia (Burger, 1990) has been atempted here. However, the FAD of the species in Group III remains unknown due to the lack of rock samples below the level of Unit D in the studied section (Fig. 3).

4.3. Implication of Palaeoecology

The abundance of pteridophytic spores suggests that herbaceous hygrophilous elements such as ferns and lycophytes were the major component of the vegetation in damp habitats. The low representation of gymnospermous bisaccate pollen and the presence of costate spores (*Cicatricosisporites* spp.) might possibily reflect the retreat of the arborescent vegetation in the coastal sites of the study area, as shown in Fig. 2, and discussed in Kozai *et al*., (2005).

The abundant land plant remains, especially dark brown to black wood fragments characterizes the palynofacies of the studied samples. Yellowish to brown plant matter and aggregations of granular organic matter are frequent. The spores and pollen specimens, broken and distorted, have translucent or peeled-off exinal surface. This might be because of thermal maturity. The composition of the palynological assemblage supports depositional environments (in general flood plain to tidal flat) for the studied section (Fig. 2), which are elucidated by the faunal data (brackish or freshwater bivalves) and the sedimentary analysis.

Table 3. Species identified in the present spores-pollen assemblage, are here categorized into Group-I, II and III, to show their stratigraphic occurrences. Each group delineates varied horizons with in the Lower Cretaceous palynoflora (for details see in Helby et al., 1987; Burger 1990; Vijaya 1999)

Group-I Occurring at the basalmost Cretaceous and continue within the Lower Cretaceous	Group-II Incoming in the middle of the Lower Cretaceous	Group-III Defining the upper part of the Lower Cretaceous
Aequitriradites verrucosus *Ruffordiaspora australiensis* *Ruffordiaspora ludbrookae* *Classopollis classoides* *Concavissimisporites penolaensis* *Concavissimisporites verrucosus* *Contignisporites* spp. *Gleichennidites circinidites* *Impardecispora* spp. *Kraeuselisporites majus* *Podosporites microsaccatus* *Polycingulatisporites reduncus*	*Cicatricosisporites annulatus* *Cingutriletes clavus* *Cooksonites variabilis* *Coptospora microgranulosa* *Dictyotosporites filosus* *Foraminisporis wonthaggiensis* *Klukisporites venkatachalae* *Matonisporites cooksoni* *Polycingulatisporites radiatus*	*Antulsporites distaverrucosus* *Appendicisporites* spp. *Contignisporites crenatus* *Cooksonites variabilis* *Coptospora verrucosa* *Couperisporites* spp. *Crybelosporites striatus* *Dictyotriletes pseudoreticulatus* *Foraminisporis asymmetricus* *Gabonisporis* spp. *Januasporites* spp. *Leptolepidites rimatus* *Lycopodiacidites dettmannae* *Pilosisporites* spp. *Santhalisporites bulbosus* *Trilobosporites* spp. *Triporoletes* spp.

5. Conclusions

The palynomorph assemblage recovered from the middle part of the Yunoki Formation, displays much similarity with many other palyno-assemblages of late Early Cretaceous age, on record in Australia, India, Europe and China. Of the three groups of spores and pollen species categorized herein in Table 3, Group III puts the present assemblage close with the *Foraminisporis asymmetricus* Palynozone, of Barremian to Aptian age (Burger, 1995; Vijaya, 1999, 2004). Faunal evidence in the studied interval suggests a Barremian age (Kozai and Ishida, 2003). No sharp line can possibly be drawn between Barremian and Aptian based on the FAD of spores.

The sedimentological analysis puts forward a flood plain to tidal flat depositional environment for the middle part of the Yunoki Formation (Fig. 2). The apparent poor preservation of the costate spores and gymnosperm pollen appear to be due to the relatively high thermal maturity of organic matter.

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References

ARIAS C. & DOUBINGER J. 1980. La Limite Aptien - Albien Dans Le Secteur du Mompichel (Albacete). *Cretaceous Research* 1, 235-251.

BURGER D. 1980. Palynological studies in the Lower Cretaceous of the Surat Basin, Australia. *Bureau of Mineral Resources, Australia, Record* 189, 106.

BURGER D. 1990. Australian Phanerozoic timescales: 9. Cretaceous biostratigraphic charts and explanatory note. *Bureau of Mineral Resources, Austrtalia, Record* 39, 1-36.

BURGER D. 1995. Timescale: 9. Cretaceous Australian Phanerozoic timescales, biostratigraphic charts and explanatory note. Secondary Series. *Bureau of Mineral Resources, Austrtalia, Record* 38, 1-35.

BATTEN D. J. 1987. Aspects of palynomorph distribution, floral provinces and climate during the Cretaceous. *Geologisches Jahrbuch* A 96, 219-237.

COUPER R. A. 1958. British Mesozoic microspores and pollen grains. *Palaeontographica* 103, 75-119.

DETTMANN M. E. 1963. Upper Mesozoic microfloras from south-eastern Australia. *Proceedings of the Royal Society of Victoria* 77, 1-148.

DETTMANN M. E. & PLAYFORD G. 1969. Palynology of the Australian Cretaceous: A review. *In* K. S. W. Campbell (editor), *Stratigraphy and Palaeontology, Essays in Honour of Dorothy Hill*, 174-210.

DETTMANN M. E., MOLNAR R. E., DOUGLAS J. G., BURGER D., FIELDING C., CLIFFORD H. T., FRANCIS J., JELL P., RICH T., WADE M., RICH P. V., PLEDGE N., KEMP A. & ROZEFELDS A. 1992. Australian Cretaceous terrestrial faunas and floras: biostratigraphic and biogeographic implications. *Cretaceous Research* 13, 207-262.

HELBY R. J., MORGAN R. & PARTRIDGE A. D. 1987. Palynological zonation of the Australian Mesozoic. *Memoirs of Association Australasian Palaeontologists* 4, 1-94.

HERNGREEN G. F. W. & CHLONOVA A. F. 1981. Cretaceous microfloral provinces. *Pollen et Spores* 23, 441-555.

HUANG R. & LONG W. 2008. Sporopollen assemblage from the Lumuwan Formation at the Hongmao section of Ledong County, Hainan and their stratigraphical significance. *Acta Micropalaeontologica Sinica* 25, 78-90.

KIMURA T. 1987. Recent knowledge of Jurassic and Early Cretaceous floras in Japan and phytogeography of this time in east Asia. *Bulletin of Tokyo Gakugei University* 39, 87-115.

KIMURA T. & HIRATA M. 1975. Early Crataceous plants from Kochi Prefecture, Southwest Japan. *Memoirs of the Natural Science Museum, Tokyo* 8, 67-90.

KOZAI T. & ISHIDA K. 2003. Early Cretaceous non-marine bivalve faunal groups from Central and East Shikoku, Japan. *Memoir of the Fukui Prefectural Dinosaur Museum* 2, 133-148.

KOZAI T., ISHIDA K., HIRSCH F., PARK S. O. & CHANG K. H. 2005. Early Cretaceous non-marine mollusk faunas of Japan and Korea. *Cretaceous Research* 26, 97-112.

LIU Z. 2000. Early Cretaceous sporopollen assemblage from the Hanxia of Yumen in Gansu, NW China. *Acta Micropalaeontologica Sinica* 17, 73-84.

LI W. & LIU Z. 1994. The Cretaceous palynofloras and their bearing on stratigraphic correlation in China. *Cretaceous Research* 15, 333-365.

MCLOUGHLIN S., HAIG D. W., BACKHOUSE J., HOLMES M. A., ELLIS G., LONG J. A. & MCNAMARA K. J. 1995. Oldest Cretaceous sequence, Giralia Anticline, Carnarvon Basin, Western Australia: late Hauterivian-Barremian. *Journal of Australian Geology and Geophysics* 15, 445-468.

NICHOLS D. J. 2003. Biodiversity changes in Cretaceous palynofloras of eastern Asia and western North America. *Journal of Asian Earth Sciences* 21, 823-833.

OISHI S. 1940. The Mesozoic floras of Japan. *Journal of the Faculty of Science, Hokkaido Imperial University* 4, 307-312.

PHLLIPS P. P. & FELIX C. J. 1971. A study of Lower and Middle Cretaceous spores and pollen from the southeastern United States 1. *Pollen and Spores* 2, 279-384.

PLAYFORD G. 1971. Palynology of basal Cretaceous (Swan River) strata of Saskatchewan and Manitoba. *Palaeontology* 14, 533-565.

POCOCK S. A. 1962. Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the Western Canada plains. *Palaeontographica* 111, 1-95.

SCHRANK E. 1994. Palynology of the Yesomma Formation in northern Somalia: A study of pollen, spores and associated phytoplankton from the Late Cretaceous Palmae province. *Palaeontographica* 231, 63-112.

SINGH C. 1964. Microflora of the Lower Cretaceous Manville Group, east-central Alberta. *Research Council of Alberta, Bulletin* 15, 1-238.

SINGH C. 1971. Lower Cretaceous microfloras of the Peace River area, Northwestern Alberta. *Research Council of Alberta, Bulletin* 28, 1-299.

SINGH H. P. & VENKATACHALA B. S. 1988. Upper Jurassic-Lower Cretaceous spores-pollen assamblages in the Peninsular India. *Palaeobotanist* 36, 168-170.

SRIVASTAVA S. K. 1972. Systematic description of some spores from the Edmonton Formation (Maestrichtian), Alberta, Canada. *Palaeontographica* 139, 1-149.

SRIVASTAVA S. K. 1994. Evolution of Cretaceous phytogeoprovinces, continents and climates. *Review of Palaeobotany and Palynology* 82, 197-224.

TANAKA H., KOZAI T. & TASHIRO M. 1984. Lower Cretaceous stratigraphy in the Monobe area, Shikoku. *Research Report of Kochi University, Natural Science* 32, 215-223.

TASHIRO M. & KOZAI T. 1984. Bivalve fossils from the type Monobegawa Group (Part 1). *Research Reports of Kochi University, Natural Science* 32, 259-293.

TIWARI R. S. & TRIPATHI A. 1995. Palynological assemblages and absolute age relationship of Intertrappean beds in the Rajmahal Basin, India. *Cretaceous Research* 16, 53-72.

TRIPATHI A. 1995. Diversity in Pteridophytic spore population through intertrappean sequence in Rajmahal Basin and palaeoclimatic interpretation. *Indian Fern Journal* 12, 59-69.

TRIPATHI A., TIWARI R. S. & PRAMOD K. 1990. Palynology of the subsurface Mesozoic sediments in Rajmahal Basin, Bihar. *Palaeobotanist* 37, 367-388.

UMETSU K. & SATO Y. 2007. Early Cretaceous palynomorphs assemblage from the Miyako and Tetori

Groups, Japan, and their implication to paleophytogeographic provinces. *Review of Palaeobotany and Palynology* 144, 13-24.

VARMA Y. N. R. & RAMANUJAM C. G. K. 1984. Palynology of some Upper Gondwana deposits of Palar Basin, Tamil Nadu, India. *Palaeontographica* 190, 37-86.

VIJAYA 1999. Palynological dating of the Neocomian-Aptian succession in the Indian Peninsula. *Cretaceous Reasearch* 20, 597-608.

VIJAYA 2004. Palynostratigraphy of the Permian Coal Measures and the Mesozoic succession in Borehole DPD-6, Pachami area, West Bengal, India. *Palaeontographica* 267, 33-55.

WALKER R. G. & CANT D. J. 1984. Sandy fluvial system. *In* Walker, R. G. (editor), *Facies Models 2 nd Edition*, 71-89, Geological Association of Canada, Canada Reprint Series 1.

WAN C., QIAO X., KONG H., JIN Y., SUN Y., LIU P., YANG J., & REN Y. 2002. Early Cretaceous spores-pollen assemblages from Bei'an area, Heilongjiang province. *Acta Micropalaeontologica Sinica*, 19, 83-90.

YABE H. 1913. Mesozoische Pflanzen von Omoto. *Science Report, Tohoku Imperial University, Second Series* 1, 57-64.

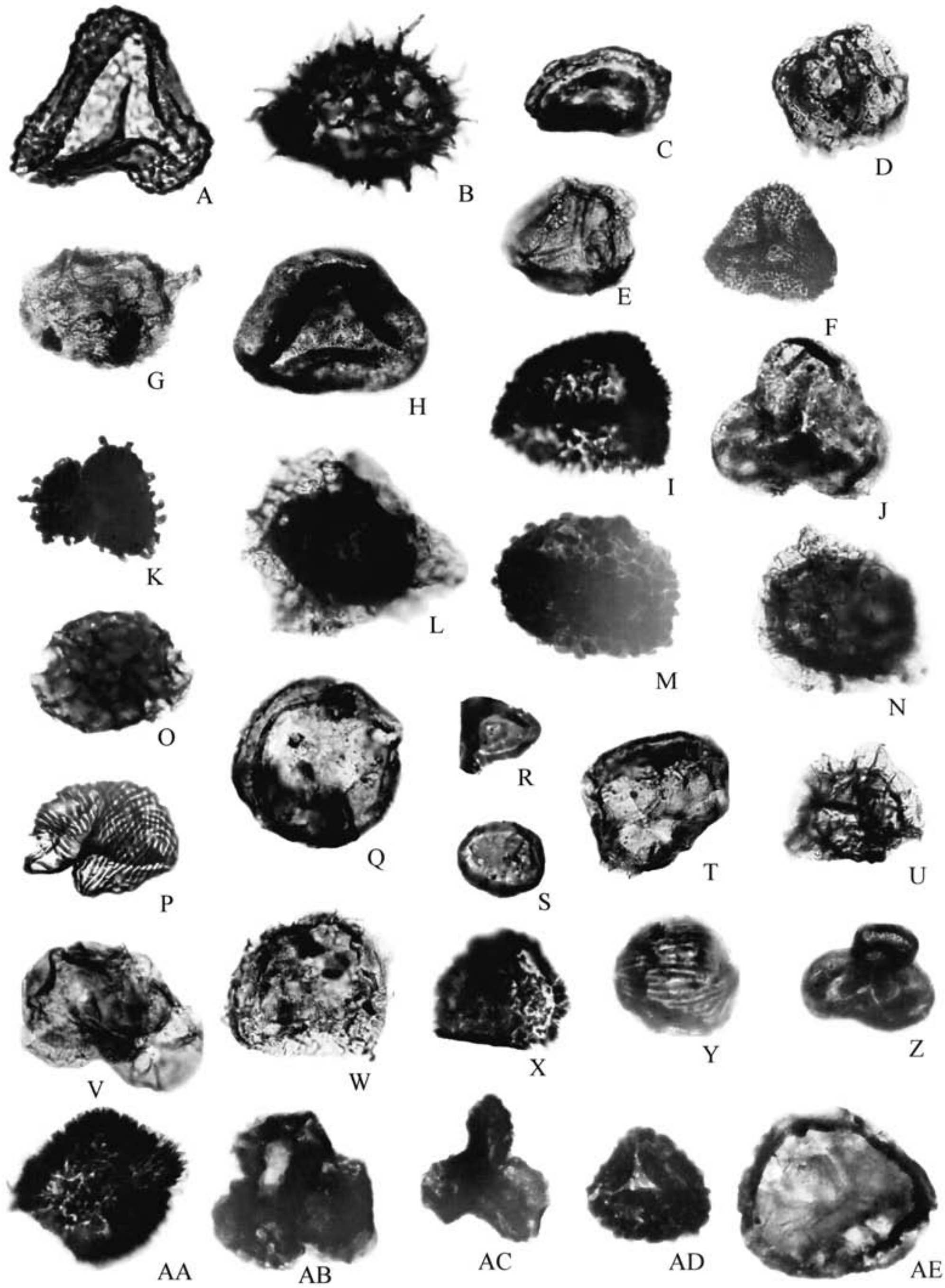

Fig. 4 Palynological slides numbered from 13321 to 13325 contain these figured specimens of spores and pollen in the productive samples, and are stored in the Museum at Birbal Sahni Institute of Palaeobotany. All photographs are x 500, except a few mentioned herein.

A, *Trilobosporites apiverrucatus*. B, *Echinatisporis varispinosus*. C, *Polycingulatisporites radiatus*. D, *Crybelosporites* sp. E, *Crybelosporites stylosus*. F, *Foraminisporis asymmetricu.s* G, *Crybelosporites striatus*. H, *Dictyophyllidites* sp. I, *Leptolepidites rimatus*. J, *Concavissimisporites penolaensis*. K, *Neoraistrickia truncates* (x 300). L, *Aqueitriradites* sp. N, *Kraeuselisporites* cf. *majus*. M, *Verrucosisporites kazigaonensis*. O, *Triporoletes reticulatus* P, *Cicatricosisporites hallei*. Q, *Coptospora* sp. R, *Polycingulatisporites reduncus*. S, *Taurocusporites* sp. T, *Triporoletes* sp. U, *Januasporites reticularis*. V, *Classopollis classoides* (tetrad). W, *Dictyotosporites filosus*. X, *Antulsporites* cf. *distaverrucosus*. Y, *Cicatricosisporites annulatus*. Z, *Concavisporites juriensis*. AA, *Gabonisporis labyrinthus*. AB, *Riccisporites convolutes* (x 300). AC, *Concavissimisporites verrucosus* (x 350). AD, *Leptolepidites verrucatus*. AE, *Coptospora verrucosa*.

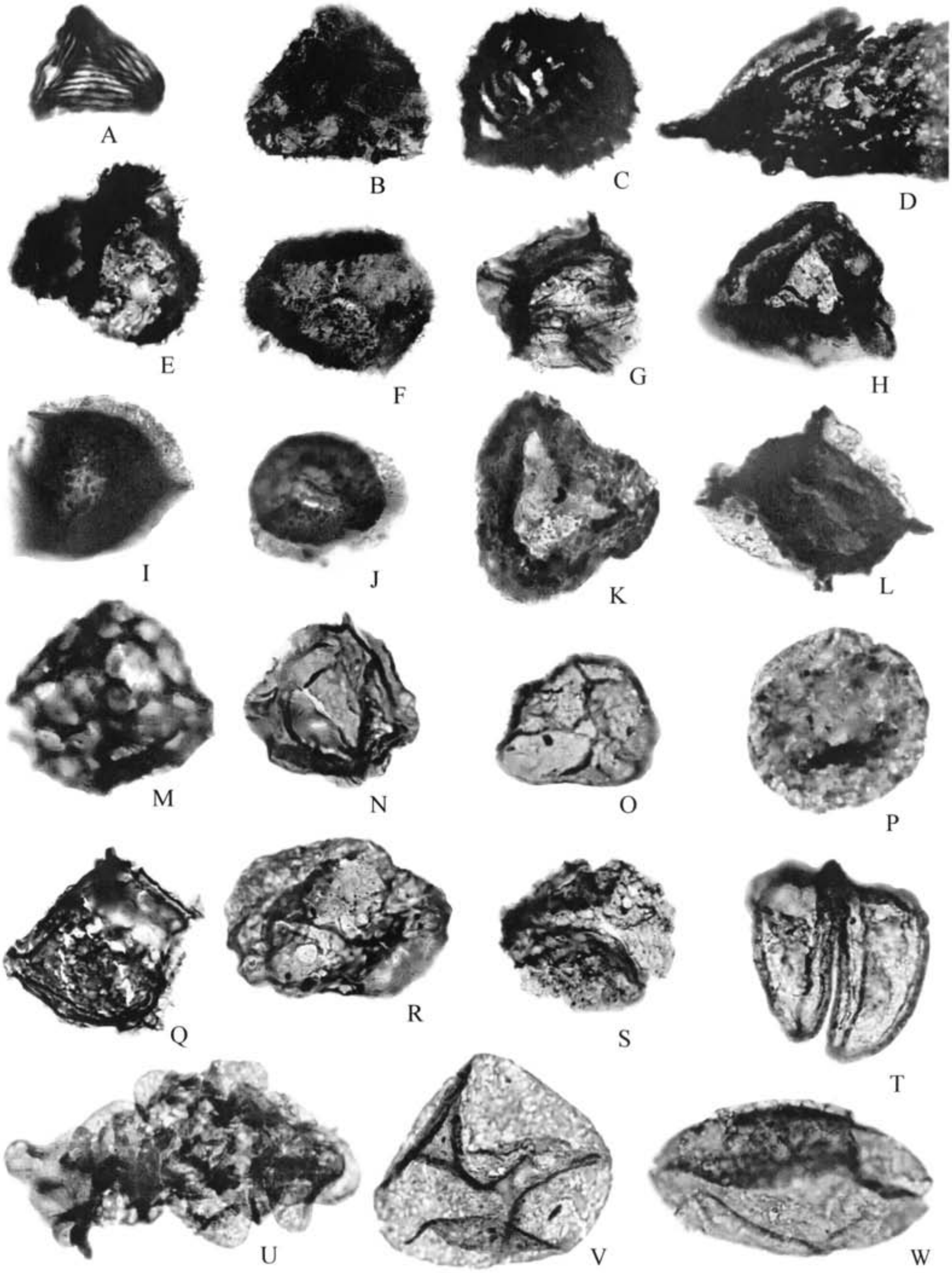

Fig. 5 Spores and pollen identified in the productive samples. All photographs are x 500, except a few mentioned herein.

A, *Ruffordiaspora ludbrookiae*. B, *Pilosisporites trichopapillosus*. C, *Cicatricosisporites pseudotripartitus*. D, *Appendicisporites problematicus*. E, *Pilosisporites grandis*. F, *Pilosisporites verus*. G, *Appendicisporites spinosus*. H, *Cicatricosisporites hughesi*. I, *Aequitriradites verrucosus*. J, *Couperisporites tabulatus*. K, *Cooksonites variabilis*. L, *Couperisporites* sp. M, *Dictyotriletes pseudoreticulatus* (x 600). N, *Callialasporites trilobatus*. O, *Triporoletes radiatus* (x 350). P, *Callialasporites monoalasporus*. Q, Unidentified Type A (x 350). R, *Podocarpidites multesimus*. S, *Podosporites microsaccatus*. T, Unidentified Type B. U, *Laevigatosporites ovatus*. V, *Microreticulatisporites* sp. W, *Schizosporis parvus*.

Spores-Pollen Assemblage from the Yunoki Formation of the Monobegawa Group, South-West Japan

KOZAI Takeshi* and VIJAYA**

Abstract

The middle part of the Lower Cretaceous Yunoki Formation, Monobegawa Group of Outer Zone of South-West Japan encompasses terrestrial input as flood plain to tidal flat deposits. Several levels contain wood and plant remains of the Ryoseki-type flora. This is the first time that an assemblage of spores and pollen is found in the Monobegawa Group of the Outer Zone of SW Japan. The diversified assemblage includes biostratigraphically significant taxa, such as *Coptospora verrucosa, Cooksonites* spp., *Trilobosporites* spp., *Pilosisporites* spp., *Lycopodiacidites dettmannae, Gabonisporis papillosus, Appendicisporites* spp. and *Couperisporites* spp. This palynoflora is representative of the Lower Cretaceous of Gondwana and Europe. The assemblage is referable to the *Foraminisporis asymmetricus* Palynozone of Barremian to Aptian age. The relative abundance of spores suggests a moist climate of origin.

*Laboratory of Geosciences, Naruto University of Education, Naruto-City, Tokushima 772-8502, Japan
**Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow-226007, India