PALYNOLOGICAL ASSEMBLAGES FROM LATE CRETACEOUS TO TERTIARY DEPOSITS OF KACHI-1 WELL, BLOCK II, YELLOW SEA BASIN, KOREA

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ABSTRACT

Thirty one samples from Late Cretaceous and Tertiary interval sections (468-783· m) of the Kachi-1 Well in Block II, Yellow Sea Basin, have been analysed for their terrestrially derived palynofloras.

The systematic study of the palynomorphs recovered has yielded one hundred and fifty-five taxa; forty-three species of spores belonging to twenty-eight genera, seventy-seven pollen assignable to forty-three genera, and twenty-seven species assignable to fifteen genera and eight fungal remains.

The results of both qualitative and quantitative analysis propose a succession of eight terrestrial palynomorph associations. Seven associations are erected in Late Maastrichtian and one in Early to Middle Miocene. Age determinations are on the basis of palynomorph taxa alone for the all associations. The Late Cretaceous/Tertiary unconformity is recognised at between 603 and 613 m, based on the palynological data.

The sedimentary basin during the Late Cretaceous seem to be lowland shallow marginal lacustrine with stagnant, mesotrophic conditions. On the other hand, the basin during the Early-Middle Miocene is considered to have been characterised by lowland swamp areas. The palaeoclimatic conditions during the Late Cretaceous are considered to be humid tropical to subtropical, while during the Early to Middle Miocene they are considered to be warm temperate with humid conditions.

A comparison of palynomorph assemblages between the present study and the previous studies of Late Cretaceous in Circum-Pacific Northern Hemisphere

is made. These assemblages reveal that lower sections (612-783 m) of the Kachi-1 well belong to the Late Cretaceous *Aquilapollenites* province of Herngreen and Chlonova (1981) and Srivastava (1981, 1994).

1. Introduction and Geology

The Yellow Sea Basin is an intracratonic pull-apart feature that is oriented generally E-W (Fig. 1). Transtensional border faults along the northern and southern flanks of the Basin are believed to exhibit relative left-lateral movement. Tertiary extension and subsequent non-marine deposition with localised compression/wrenching followed as the pull-apart basin evolved. Palaeogene sediments fill the majority of the basin below the regional Pliocene unconformity, which marks the transition from non-marine to marine deposition. Local and sub-regional unconformities abound throughout the basin and serve to mark episodes of uplift and erosion, the most notable of which is the Neogene unconformity.

Block II occupies only the southeastern portion of the Yellow Sea Basin which is one of a number of Mesozoic-Tertiary, non-marine, back-arc, transtensional pull-apart basins that are distributed along a general NE-SW trend in China and into the Yellow Sea (Fig. 1). Block II contains three sub-basinal areas within the larger Yellow Sea Basin. These subbasins are Western, Central and Eastern Basins in eastward.

The western Basin, where the Kachi-1 Well was drilled, is situated in the very western portion of Block II, but extends an unknown distance to the northwest beyond the boundary of the block. It is known that the basin does dip down to the west and northwest from the Western boundary of the Block. Extensional tectonics predominated in this basin from Cretaceous through Paleogene time when non-marine sediments were deposited. At the Kachi-1 location, the reactivation of an old normal fault, which marked the boundary of a classic half-graben in the Cretaceous and Palaeogene, produced a large inverted structure. Transpression along this old fault began in Late Miocene time and is still active at present. This Miocene to Recent strike-slip fault is probably due to left-lateral movement along the border fault to the south.

At the Kachi-1 site deposition of syn-rift fluvial/lacustrine sandstones and claystones occurred adjacent to a large northwest-southeast trending basin-bounding fault during a period of extension from the Cretaceous through Oligocene. The graben was infilled by post-rift red beds in Miocene time. The basin was inverted in the Late Miocene with the reactivation of older faults in a change to compressional and transpressional tectonics. Incursion of shallow epicontinental seas buried the structures with flat-lying Plio-Pleistocene marine sediments. Between 468 and 603 m the lithologies are primarily poorly cemented quartz sand/sandstone with minor interbeds of light grey, carbonaceous clay/claystone and woody lignite. The interval from 604 to 783 m consists predominantly of Claystone with minor thin interbeds of siltstone, sandstone and limestone (Fig.2).

2. Palynological associations (see Figs 2-3)

Association A(K)1: interval: 468 to 486 m; samples: K1560 to K1620; age: Early to Middle Miocene. This association is characterised by the dominance of *Magnastriatites granulastriatites* (38 %) together with abundance of *Inaperturopollenites dubius* (12

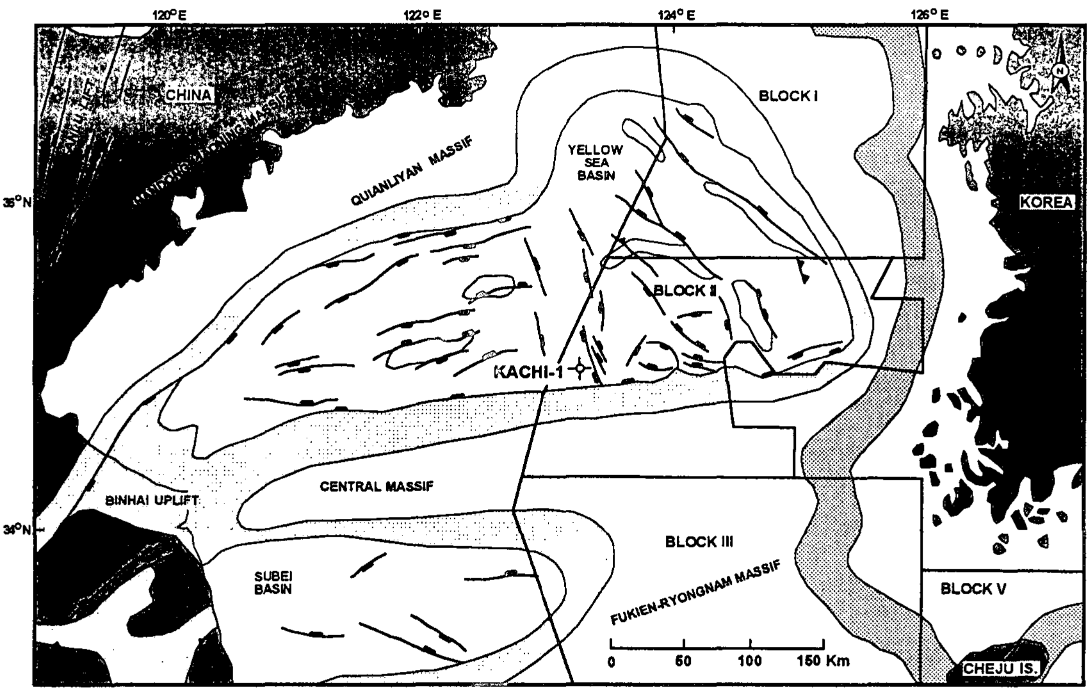

Fig. 1. Tectonics of the Yellow Sea Basin and neighbouring area (from Marathon Peteroleum Korea).

: Land.

: areas underlain by relatively thin Neogene sedimentary section on granitic/metamorphic basement massif.

: areas without any substantial sedimentary cover and primarily with exposed basement rocks.

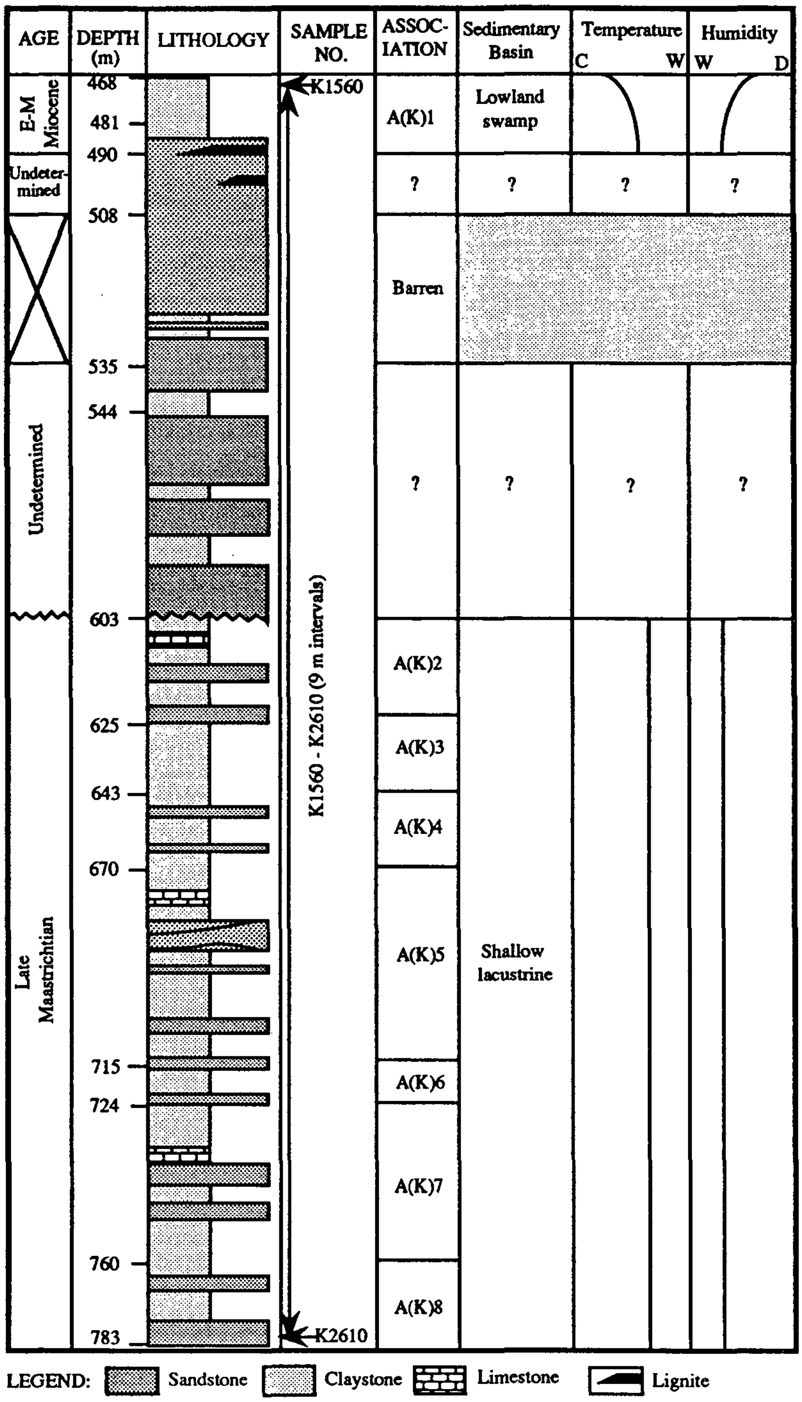

Fig. 2. Composite diagram illustrating the interpreted palaeoenvironment of the Kachi-1 well. C., W. = cool, warm in temperature; W., D. = wet, dry in humidity.

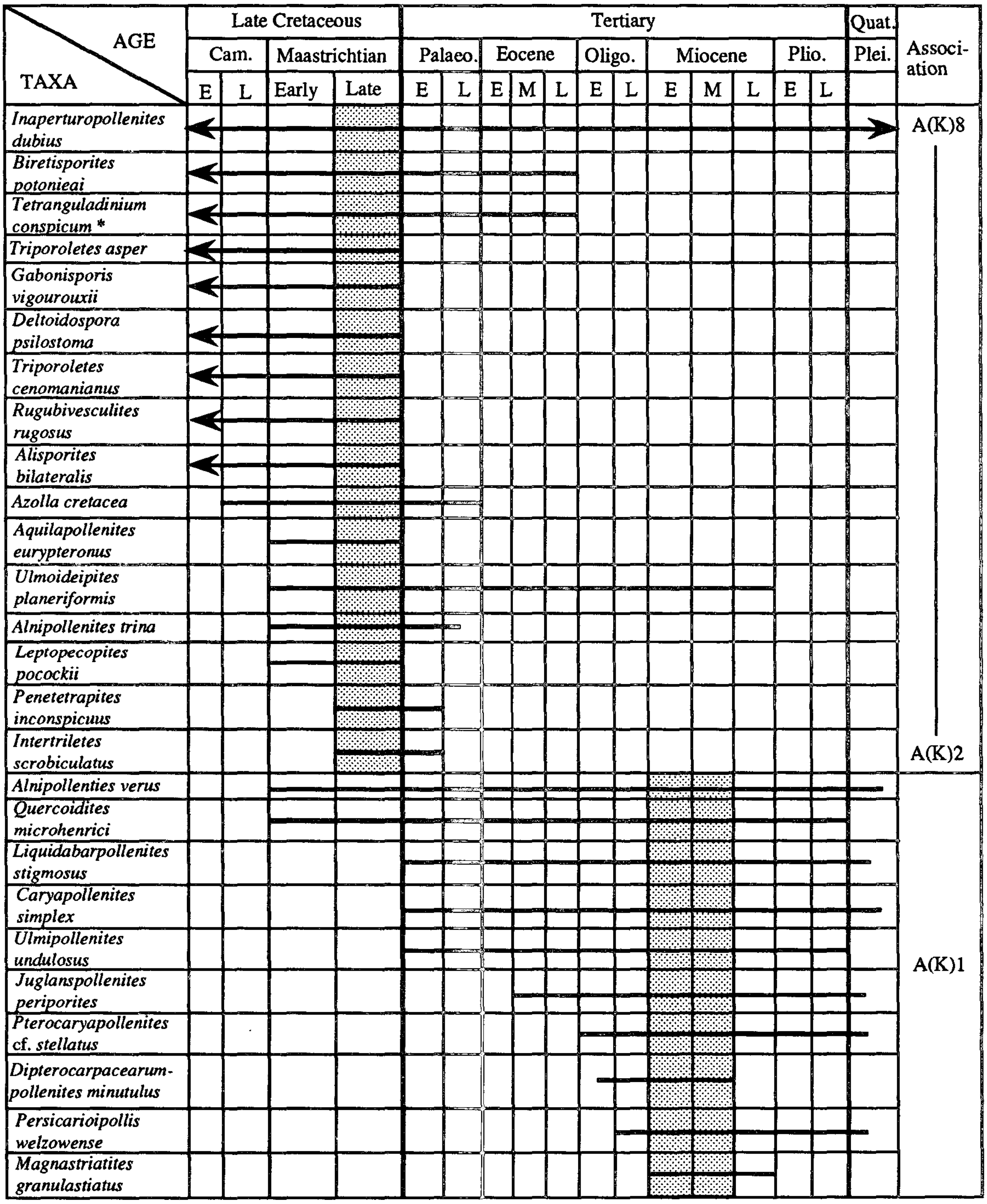

Fig. 3. Stratigraphic ranges of selected species recognised in the Kachi-1 well.
Stippled areas indicate the relative position of the Associations A(1)-A(K)8.
* Fresh-water algae.

%). Other characteristic taxa contain the common occurrences of *Persicarioipollis welzowense* (7.8 %), *Dipterocarpacearumpollenites minutus* (7 %) and *Liquidambar-*
pollenites minutus (5 %), and the few occurrences of *Pterocaryapollenites* cf. *stellatus* (4.5 %), *Quercoidites microhenrici* (3.7 %). The occurrences of *M. granulastriatites, D. minutus* and *P. welzowense* are remarkably decreased in the lower section of the association. The bottom boundary of the association is indicated by the disappearance of *M. granulastriatites, D. minutus, P. welzowense* and *P. meuseli.*

Low palynomorphs recovery intervals (495-603 m)

Three low palynomorph recovery intervals are recognised, and the contents of these intervals are not enough to create palynological association units in this study. The three intervals are:

1) 495-504 m: This interval is characterised by the recovery of only *Juglanspollenites periporites* (only 2 specimens of the total counts in K1650) and *L. minutus* (only 1 specimen of the total counts in K1680). This interval, therefore, is not suitable to create a palynological association, and the taxa could be considered to be caved from the top section.

2) 513 to 531 m: This interval is barren.

3) 540-603 m: This interval is characterised by only 11 species representing a very low abundance. The taxa present include *Caryapollenites simplex* and *Ulmipollenites undulosus, Pterocaryapollenites* cf. *stellatus*, *Alnipollenites verus, Inaperturopollenites dubius, Pinuspollenites* spp. and *Liquidambarpollenites* (including *L. minutus* and *L. stigmosus*). Therefore it is not enough to create a palynological association.

Association A(K)2: interval: 612 to 621 m; samples: K2040 to K2070; age: Late Maastrichtian. This association is characterised by dominant taxa including *Azolla* spp. (15 %) and *S. miocenica* (19 %) in association with an abundance of *C. minor* (14 %), *Deltoidospora psilostoma* (12 %), *D. granulatus* (7.3 %) and *Brazilea circularis* (5.6 %). This association differs from the underlying one by the absence of Triporoletes sp., *Klukisporites punctatus, Podocarpidites nageiaformis, Alnipollenites trina, Ulmoideipites planeraeformis, U. tricostatus, Leptopecopites pocockii* and *Cranwellia striatus*, and by the presence of species of *Goshispora* sp. *A, Intertriletes scrobiculatus, D. psilostoma, K. laevigatus* and

T. asper. The last occurrences of *Azolla* spp., *C. minor, T. cenomanianus, D. psilostoma, Goshispora* sp. A, *D. granulatus, Diporocolpopollenites kachiensis, Penetetrapites inconspicuus, Aquilapollenites eurypteronus* and *Rugubivesiculites rugosus* reflects the top boundary of the association. The bottom boundary of the association is recognised by markedly increase *D. granulatus*, and by the presence of decreased *C. minor* and *D. psilostoma*.

Association A(K)3: interval: 630 to 639 m; samples: K2100 to K2130; age: Late Maastrichtian. The sporomorphs of this association are dominated by *Azolla* spp. (18.9 %), *D. granulatus* (17 %) and *S. miocenica* (16 %). The boundary between this association and the overlying one is recognised by the last occurrences of taxa comprising *Triporoletes* sp., *K. punctatus, Polypodiaceoisporites retirugatus, Pterisisporites undulatus, Podocarpidites nageiaformis, A. trina, Ulmoideipites planeraeformis, U. tricostatus, Phyllocladidites inchoatus, Leptopecopites pocockii, Tricolpites reticulatus, Cranwellia striatus*. This association can be distinguished from the overlying association by the absence of *Goshispora* sp. *A, Intertriletes scrobiculatus, Klukisporites* sp., *T. asper*.

Association A(K)4: interval: 648 to 666 m; samples: K2160 to K2220; age: Late Maastrichtian. This association is dominated by *Azolla* spp. (15.6 %), *D. granulatus* (12.4 %) and *S. miocenica* (15 %). The bottom boundary of this association is recognised by the presence of markedly decreased *Azolla* spp., *D. granulatus* with increased *S. miocenica*. The top boundary of the association is also indicated by the last occurrences species of *Goshispora* sp. B, *Alisporites bilateralis, Inaperturopollenites magnus, Ephedripites jansonii, E. praeclarus, Tricolpites reticulatus* var. *Retitriletes* sp., *Dictyophyllidites* spp., *Triporoletes reticulatus, Hamulatisporis hamulatis, Biretisporites* sp. C, *Rugubivesiculites convolutes, Jiangsupollis radiatus* and *Wodehouseia spinata* are restricted occurrence taxa within this association.

Association A(K)5: interval: 675 to 711 m; samples: K2250 to K2370; age: Late Maastrichtian. The palynofloras of this association are dominated by *Azolla* spp. (9.4 %), *D. granulatus* (9.2 %) and *S. miocenica* (18.6 %). *C. minor* shows increased gradually throughout the studied sections of the association. *Triporoletes cenomanianus* is slightly increased from the succeeding association. *Klukisporites foveolatus* appears to be restricted occurrence within this association. *Biretisporites* sp. B and *Multinodisporites praecultus* have their last occurrence taxa in this association. *P. inconspicuus* is present to be decreased, and then increased again toward the bottom of the association. The frequency of *D. granulatus* and *I. dubius* shows little variation throughout the sections of the association. *Chomotriletes minor, K. bivalvis* appear to be decreased throughout the sections of the association, while *S. microcircularis, Ovoidites ligneolus, Tetranguladinium conspicum, Botryococcus braunii* increase gradually. This association differs from the underlying one by a sharply increased *Azolla* spp. and *D. granulatus* with considerably increased *S. miocenica* and *P. inconspicuus.* The bottom boundary of this association is, also, indicated by the disappearance of the species of *Osmundacidites wellmanii, B. potoniaei, D. psilostoma, C. australis, P. undulosus, M. praecultus, I. hiatus, P. minutus, R. rugosus, U. planeraeformis, U. tricostatus* and *I. magnus.*

Association A(K)6: depth: 720 m; sample: K2400; age: Late Maastrichtian. This association is characterised by the dominance of *S. miocenica* (37 %). A pronounced decline in *Azolla* spp. and *D. granulatus* contrasts with the increase in frequency of *P. inconspicuus* indicating a new association which consists of a single sample. The top boundary of the association is identified by the absence of taxa which are present in preceding association. These characteristic taxa are *O. wellmanii, B. potoniaei, D. psilostoma, C. australis, P. undulosus, M. praecultus, I. hiatus, P. minutus, R. rugosus, U. planeraeformis, U. tricostatus* and *I. magnus.*

Association A(K)7: interval: 729 to 756 m; samples: K2430 to K2520; age: Late Maastrichtian. This association is characterised by high proportion of *D. granulatus* (13.4 %) and *S. miocenica* (17 %) which is more abundant than in the succeeding association. *S. miocenica* gradually decreases in frequency towards the bottom of the association. In contrast *Azolla* spp. shows a marked decreases from the succeeding association. The lower boundary of this association is identified by lower frequencies of *Azolla* spp. occurring with suddenly decreased *P. inconspicuus* and *S. miocenica.* Other characteristic sporomorphs include Cingutriletes sp., *Callistopollenites tumidoporus* and *Aquilapollenites spinulosus.*

Association A(K)8: interval: 765 to 783 m; samples: K2550 K2610; age: Late Maastrichtian. This association is represented by dominant taxa including *Azolla* spp. (21 %) and *S. miocenica* (27 %) throughout the studied sections in this association. I. dubius markedly increases in contrast with *D. granulatus* which considerably decreases towards the bottom of the association. The top of the association is recognised by the sudden change of the relative abundance of *Azolla* spp. and *P. inconspicuus.*

3. Palaeoenvironmental interpretation (see Fig. 2)

The interval (468-486 m) is characterised by the predominance of small aquatic fern (*Magnastriatites granulastriatus*) and pollen such as *Persicarioipollis, Inaperturopollenites* and *Alnipollenites* derived from auqatic and swamp region, associated with pollen (*Liquidambarpollenites, Quercoidites, Betulaepollenites* and *Dipterocarpacearumpollenites*) from lowland deciduous broadleaved and evergreen broadleaved. This interval, also, is characteristic of humid warm temperate taxa throughout the interval. Therefore it is assumed to represent a lowland swamp surrounded by slopes on which the deciduous broadleaved trees grew under largely warm temperate with a wet conditions.

The lower interval (612-783 m) is characterised by the abundance of aquatic fern megaspores (*Azolla* and *Goshispora*) and freshwater algae, especially zygospores (*Brazilea* and *Kachiisporis*) indicating stagnant or slow-moving water in a shallow lake or pond. A diversity of spores such as *Cyathidites, Triporoletes* and *Klukisporites* from lowland communities and aquatic pollen (*Penetetrapites*) represent adjacent lowland areas. The presence of predominant Pediastrum throughout the interval indicates that sediments of the basin were deposited in a shallow lake with high pH. This interval is characterised by fairly diverse and abundant palynomorphs which may be derived from plants inhabiting humid tropical to warm temperate climate. It is concluded that interval represents a high pH, shallow marginal lacustrine environment under tropical to subtropical with a humid climatic conditions.

4. Phytogeoprovince identification in the present study

The palynofloral assemblages recognised appear to be similar to those of the Late Cretaceous sediments of China, East Siberia, Japan and the Western Interior territories of North America. Most of the recovered spores and pollen grains appear to be similar to those of the Yenisely-Amur province (Samoilovitch, 1961) within the *Aquilapollenites* phytogeoprovince (Fig. 4).

The most characteristic taxa of the interval (612-783 m) are the water fern megaspores *Azolla* and *Goshispora*; the fern miospores *Gabonisporis,* *Triporoletes, Cyathidites, Deltoidospora* and *Klukisporites*; gymnosperm and angiosperm pollen grains including *Inaperturopollenites, Rugubivesiculites, Cedripites, Dilwynites, Penetetrapites* and *Diporocolpopollenites*; fresh-water colonial green algae *Pediastrum, Savitrinia* and *Botryococcus*; Zygnematacean zygospores *Brazilea, Lecaniella, Kachiisporis* and *Tetranguladinium*; and algae uncertain affinity *Chomotriletes.* Other important pollen grains include *Aquilapollenites, Leptopecopites, Cranwellia* and *Ephedripites.*

In conclusions the lower interval is correlated with the Late Cretaceous *Aquilapollenites* province (Herngreen and Chlonova, 1981; Srivastava, 1981, 1994).

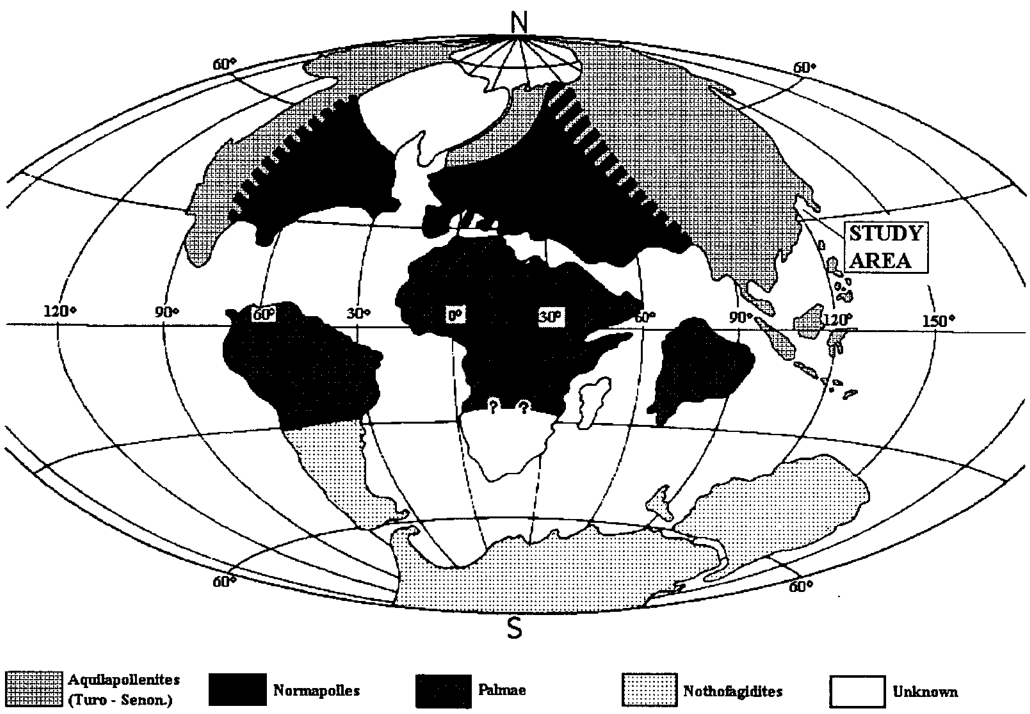

Fig. 4. Senonian phytogeoprovinces (modified Herngreen & Chlonova, 1981).

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