J.Paleont.Soc.Korea.V.14,No.1,(1998):pp.1 ~ 13

PALYNOFACIES OF THE SANSUDONG FORMATION (LOWER CRETACEOUS), JINAN BASIN, KOREA

Sangheon YI* , Hyesu YUN* , Jong-Deock LEE**
*Department of Geology, Chungnam National University, Daejon, Korea
**Department of Earth and Environmental Sciences, Chonbuk National University, Chonbuk, Korea

Abstract : A palynological investigation of the Sansudong Formation, Jinan Basin, has been carried out and a small number of poorly preserved pteridophyte spores were recorded for the first time. The palynofacies are dominated by land-derived plant debris, in particular black irregular, and black elongate wood fragments and cuticles. The colour of the spores and phytoclasts examined under a transmitted light microscope, shows that the organic matter was heated to over 200℃, indicating that it is over-mature for hydrocarbon generation. It is directly correlated with the numerical thermal alteration index of Batten (1996), being rated at 7. This reflects local metamorphism by post-depositional volcanic intrusion/extrusion along the right-lateral fault fracture zone of the basin. The relatively good sorting of the terrestrially derived palynodebris and the absence of marine microfossils suggests that the sediments comprising the Sansudong Formation were transported a fairly long distance to the depositional site near the centre of the basin where fluvio-lacustrine conditions prevailed. The synthesis of the spore assemblage recorded associated with other published data suggests that the formation is probably of Early Cretaceous (Barremian?) age.

INTRODUCTION

A number of Cretaceous non-marine sedimentary basins were developed in the southern part of the Korean peninsula (e.g. Gyeongsang, Gyeokpo, Haenam, Youngdong, Gongju, Eumsung, Poongam, Tongri and Jinan Basins). The Jinan Basin is rhomboidal in shape and relatively small being about 30 km long X 20 km wide, with NE-SW trending axis along the southwestern boundary of the Ogcheon Fold Belt. A few sedimentological and geophysical studies on the basin have been carried out (Lee, 1992; Baag and Kwon, 1994). Lee (1992) documented that it was developed by a pull-apart tectonic combination of right-stepping and right-lateral faults surrounding the basin. Baag and Kwon (1994), who used aeromagnetic data, considered the NE-SW trend of the basin to have been formed by fault movement during the Cretaceous Period.

The rock samples were initially made available for a study with emphasis on age dating and interpretation of depositional palaeoenvironment on the basis of the palynoflora they contain. However, because palynomorphs are virtually absent, it is not possible to use them for palaeoenvironmental interpretation. Other components of the palynological preparation must be used instead. Combaz (1964) first introduced the term "palynofacies" to encompass all kinds of microscopic organic matter in a palynological preparation including wood fragments, cuticles, algal remains and tissues of uncertain origin which are less easy to categorise. Palynofacies analysis is

based on the identification of individual palynomorph taxa, phytoclasts and amorphous components and the study of their absolute and relative proportions, size spectra and preservation states (e.g. Combaz, 1964; Tyson, 1993). Microscopical studies of organic matter extracted from sedimentary rocks are used for not only palaeoenvironmental interpretations (e.g. Batten, 1982; Tyson, 1993) but also the analysis of source rocks from kerogen type (e.g. Batten, 1983; Tissot and Welte, 1984; Tyson, 1993). The present study concentrates on palaeoenvironmental interpretation inferred from the palynofacies.

GEOLOGY

The Early Cretaceous Jinan Basin is bounded by the basement of Precambrian biotite gneiss, metasedimentary rock of unknown age and Jurassic granite (Fig. 1; Shimamura, 1925; Kim *et al.*, 1984; Lee, 1992). During the late Early Cretaceous (?Albian) the older Cretaceous sedimentary successions were intruded by andesitic-rhyolitic volcanics and overlain by andesitic-rhyolitic tuffs (Fig. 1; Kim *et al.*, 1984; Chang, 1985). The lithostratigraphy of the Jinan Group is still controversial and because of lateral changes of facies associations authors subdivide it differently (Fig. 2). The geologic map made by Shimamura (1925) who carried first out geological survey in the Jinan Basin is accepted here. It is considered here to comprise in ascending order (1) the Dalgil-Mandeoksan Formation composed mainly of alterations of conglomerate, sandstone and tuffaceous shale, (2) the

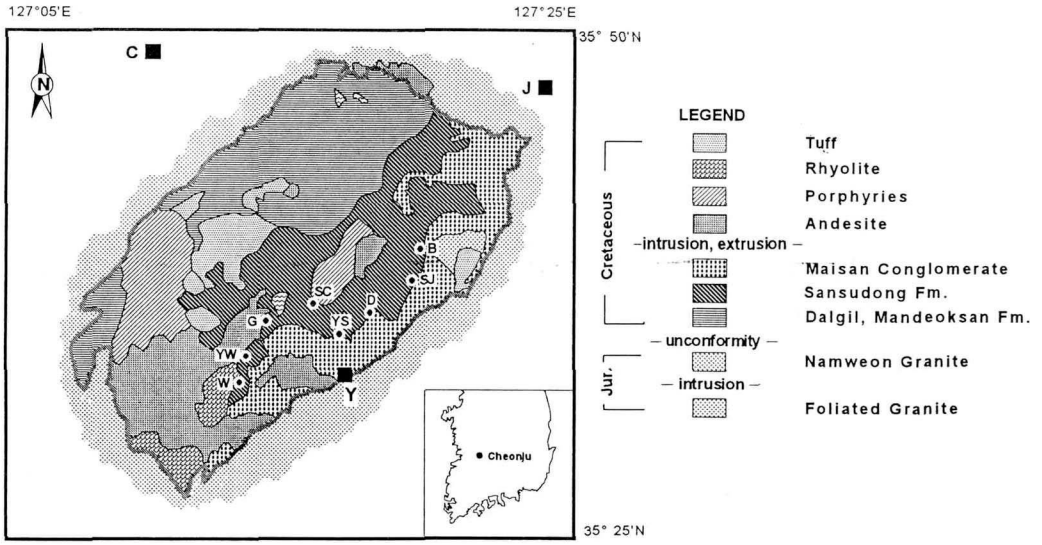


Figure 1 Geologic map of Jinan Basin and surrounding area (after Shimamura, 1925). C: Cheonju; J: Jinan; Y: Yimsil. Points of filled circles indicate sample location. Baechi (B), Seolchijae (SJ), Deockchon (D), Yongsan (YS), Seulchi (SC), Gucksabong (G), Yongwun (YW), Wunam (W).

Sansudong Formation composed mainly of grey/black shale with minor sandstone, and (3) overlain unconformately by the Maisan Conglomerate Formation confined mainly to the eastern part of the basin and consisting largely of conglomerate as the name implies (Fig. 2). Jinan strata yield a variety of fossils including tree trunks, fresh water molluscs and fish, and sedimentological features indicate that they are of fluvio-lacustrine origin (Reedman and Um, 1975; Kim *et al.*, 1984; Chang, 1985; Lee, 1992; Lee, 1997).

MATERIAL AND METHODS

Sixty-four samples of the Sansudong Formation consisting mostly of black shale and distributed generally along the NE-SW trend were collected for palynological investigation. In order to obtain palynomorphs and palynodebris standard palynological techniques of HCL (30%) and HF (40%) treatment were used, followed by separation of the unoxidised residue using a heavy liquid ($ZnCl_2$: sp. gr. 2.0). The organic residues were mounted on glass slides in glycerine jelly. The samples and strew-mounted slides used in this study are stored at Department of Geology, Chungnam National University.

PALYNOFACIES

The occurrence and composition of organic matter in sedimentary rocks depends on the types of terrestrial or aquatic environments in which it is generated, its transport to the depositional site, and

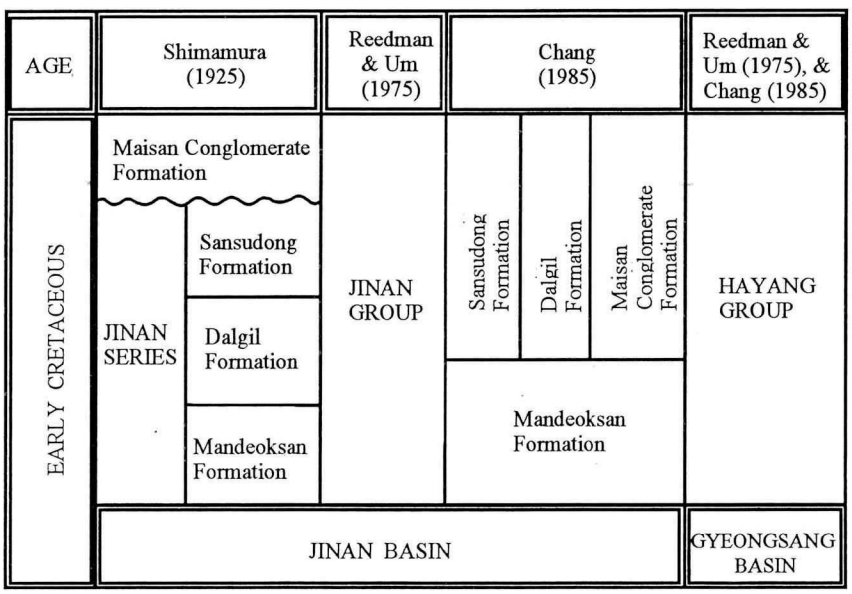


Figure 2 Stratigraphic classifications of the Jinan Group, proposed by different authors, correlate with Gyeonsang Basin

its alteration once deposited (Batten, 1996). The physio-chemical changes that take place pre- and post-deposition may have a considerable influence on the kinds of organic matter that are eventually preserved.

Since three kinds of phytoclast, namely black, opaque, wood fragments, structured wood fragments and cuticles, dominate the samples, it was not thought that statistical presentation of the palynodebris record would be helpful in palaeoenvironmental reconstruction. Counts of palynodebris were not, therefore, carried out.

Palynomorphs ; The term palynomorph refers to all different acid-resistant, organic-walled microfossils that may be encountered in a palynological preparation. Of the sixty-four samples collected from the Sansudong Formation, three (Yongwun 9-2, Deockchon 1-4 and Bachi 4-1) yielded a small number of poorly preserved palynomorphs. All are opaque/black in colour making their structure and ornamentation difficult to examine (pl. 1, figs. 1-6).

Palynodebris ; As noted above this consists predominantly of three types: (1) terrestrially derived black wood fragments of blocky to irregular shape with rounded corners (BWF; pl. 2, fig. 8), (2) elongated structured wood fragments with more or less smooth margins (ESWF; pl. 2, figs. 2-4), and (3) cuticles (pl. 2, figs. 5-7). The structures of ESWF are difficult to recognise, because of the degree of thermal alteration to which they have been subjected. The cuticles are also largely black and poorly preserved.

Sorting of palynodebris ; It is well known that palynomorphs and palynodebris behave in the same way as clastic particles of comparable specific gravity (Traverse, 1988; Chumura and Liu, 1990). Since most trends are related to sediment grain-size, large and strongly ornamented trilete spores tend to be more abundant in fluvio-lacustrine, swamp, delta-top, and continental shelf facies than elsewhere (Muller, 1959; Mudie, 1982). In general, palynomorphs and palynodebris are transported by water to depositional sites (Holmes, 1994). Chen (1987) found that many palynomorphs in the sediments of Lake Barine in Queensland, Australia are carried in it by surface runoff. Larger grains are deposited in the littoral areas, whereas smaller grains are transported to the centre of the lake by currents.

In our material, the organic matter is relatively well sorted in all of the samples, the phytoclasts ranging from 120-155 ㎛ in maximum length (400 specimens measured). The small size distribution suggests that the organic matter incorporated in the clastic sediments was transported to the central part of the Jinan Basin. The palynofacies of each of the areas sampled are of similar composition (Fig. 3).

Organic maturation ; Organic-walled microfossils which are composed of "sporopollenin", commonly better preserved in sediments than other microfossils. When not subjected to much thermal alteration they are pale in colour (e.g. yellow, yellowish-orange). With increasing temperature they gradually become darken (e.g. brown) until they are black and opaque (Raynaud and Robert, 1976). Traverse (1988) noted that sporopollenin is altered and may be destroyed in an oxidising environment or highly alkaline environment, by relatively low temperature elevation over a long time, and by high temperatures over a relatively short time as a result of, for example, volcanic intrusion.

Several numerical scales based on palynomorph colours linked with phases of organic maturation have been published during past two decades (e.g. see Correia, 1967; Staplin, 1969; Batten, 1996). The palynofacies associated with all samples in our study are opaque/black overall (pl. 3, figs. 1-6),

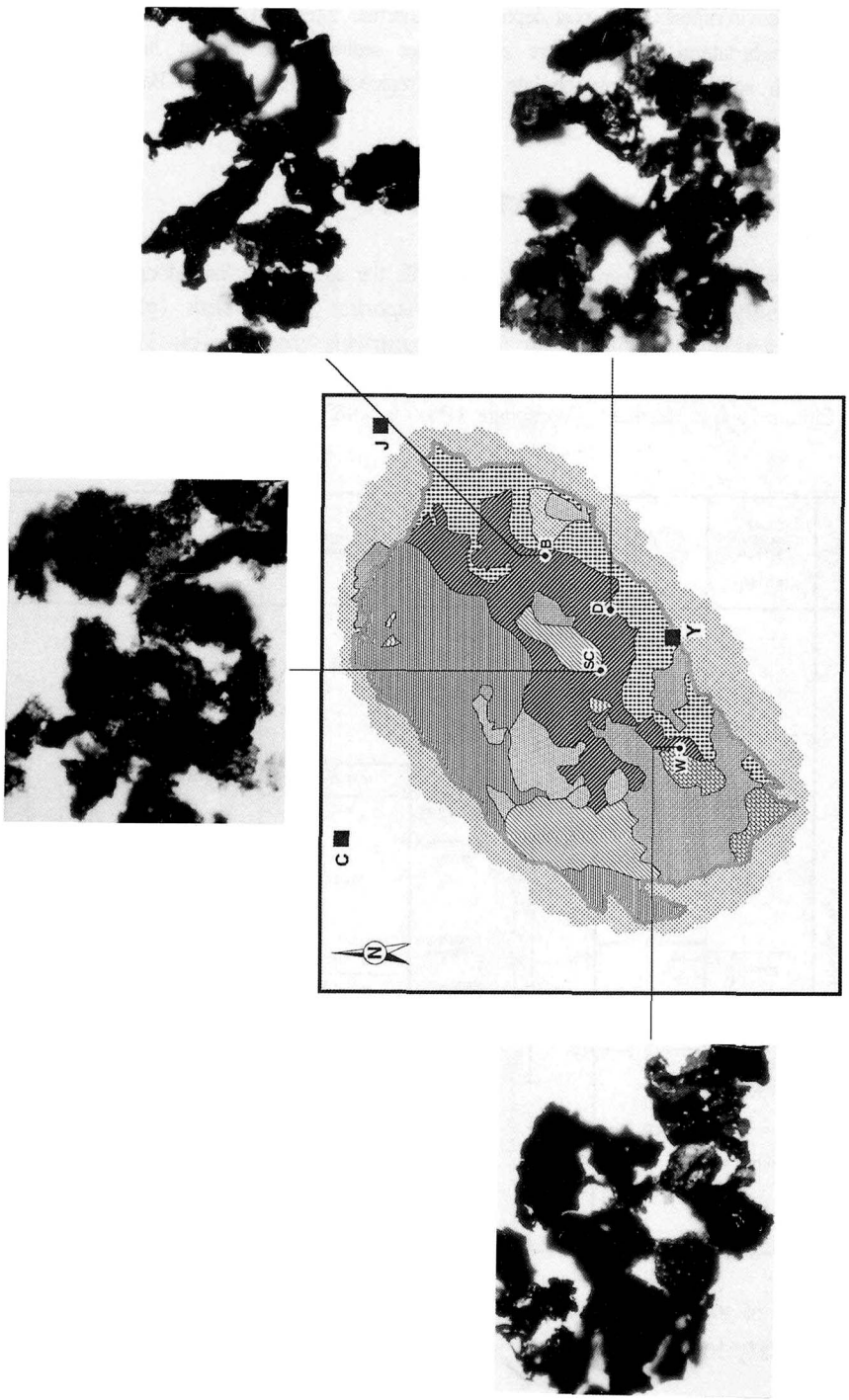


Figure 3 Palynofacies of the Sansudong Formation showing the organic matters with a similar pattern of size distribution and sorting. C: Cheonju; J: Jinan; Y: Yimsil. Points of filled circles indicate sample location Baechi (B), Deockchon (D), Seulchi (SC), Wunam (W)

and may be rated at 7 on the thermal alteration scale of Batten (1996), indicating maturation temperatures of the order of ±200℃ (Fig. 4). The palynofacies are considered to reflect fairly oxidising depositional environments and post-depositional thermal alteration as a result of volcanic intrusions along the right-lateral fault fracture zone. After sedimentation in the Jinan Basin had ceased these was much volcanism during the late Early Cretaceous (Chang, 1985; Baag and Kwon, 1994).

BIOSTRATIGRAPHY

Not enough palynomorphs have been recovered to enable the age of the Sansudong Formation to be determined precisely. Those identified are *Klukisporites southeyensis* (pl. 1, fig. 6), *Reticulatisporites semireticulatus* (pl. 1, fig. 5), *Neoraistrickia truncata* (pl. 1, fig. 1) and *Neoraistrickia* sp. (pl. 1, figs. 2-4). *K. southeyensis* is recorded from late Hauterivian to early Albian deposits of the Circum-Pacific Northern Hemisphere (Pocock, 1962; Miao *et al.*, 1984; Burden and

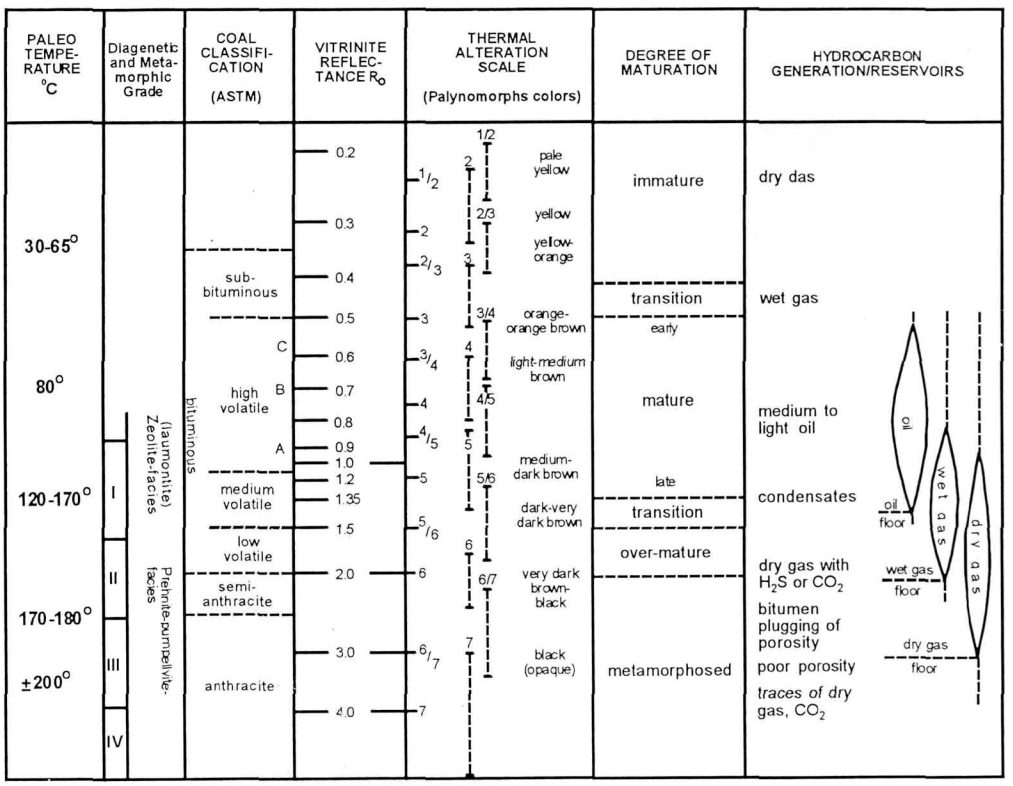


Figure 4 Correlation of thermal maturation indicators in sedimentary rocks (after Batten, 1996) ASTM: American Society for Testing, Materials.

Hills, 1989). The other three species have longer stratigraphic ranges. *R. semireticulatus* is known to range in age from Late Jurassic (Tithonian) to Early Cretaceous (late Albian) in North America and Europe (Norris, 1967; Burden and Hills, 1989). *N. truncata* occurs in Jurassic and Cretaceous strata world wide (Pocock, 1962; Norris, 1967; Miao *et al.*, 1984; Burden and Hills, 1989). Yi *et al.* (1994) recorded several palynomorph species including those mentioned above from the Jinju Formation in the Euiseong area of Korea. They assumed the age of this formation to be Barremian, basing their determination on five taxa including *Klukisporites southeyensis*.

Chang (1985) and Lee (1992) recorded plant macrofossil *Frenelopsis* sp. from the Sansudong Formation and correlated the Jinan Group with the Hayang Group (Barremian) of the Gyeongsang Basin. Recently Chun *et al* (1994) described *Frenelopsis* sp. from the Eumsung Basin, and noted that the family to which it belongs, the Cheirolepidaceae, flourished during the Barremian to Aptian period in warm dry conditions at low latitudes.

Chang (1985) correlated the age of the andesite overlying the Jinan Group with basal part of the Yuchon Volcanic Group which is regarded as ?Albian. Overall, the limited palynological, palaeobotanical and other evidence suggests that the age of the Sansudong Formation is probably Early Cretaceous, and possibly Barremian.

RESULTS AND CONCLUSIONS

The palynofacies of the samples examined are characterised by being dominated by black, opaque wood fragments, elongated structured wood fragment and cuticles with a small number of pteridophytic spores in association. Both the palynomorphs and the palynodebris are black and largely opaque, and rated at 7 on the scale of Batten (1996), indicating that the rocks are over mature with respect to the generation of hydrocarbons. The organic matter was thermally altered at high temperatures (probably over 200℃) during post depositional volcanic intrusion and extrusion along the strike-slip fault fracture zone in the Jinan Basin.

Rock-Eval pyrolysis, which was carried out on the same rock samples as the palynofacies analysis, has confirmed the degree of thermal alteration. Very low hydrogen indices (HI) indicated a loss of hydrogen at high geotemperatures (Dr. Lee, KIGAM, personal communication).

The small size range and commonly rounded character of the phytoclasts may indicate that they were transported a long distance to the sites of deposition and accumulated near the centre of the basin. The occurrence of terrestrially derived palynomorphs and phytoclasts without any marine microfossils in association suggests fluvio-lacustrine conditions. The limited palynofloras recovered and other published data are interpreted to imply that the Sansudong Formation is of Early Cretaceous (Barremian?) age.

ACKNOWLEDGEMENTS

This study was funded in part by a grant from the Korea Science and Engineering Foundation (KOSEF), awarded to the first author (YI) as a post-doctoral scholarship. It also comprises a part of the Jinan Basin research project funded by the Ministry of Education of Korea (BSRI-97-5425) and

awarded to the third author (LEE). Thanks are due to Dr. Songsuk YI, Chungnam National University, for assistance with field survey. Dr. Youngjoo Lee, Korea Institute of Geology, Mining and Materials (KIGAM), is thanked for enjoyable discussion of Rock-Eval analysis. The manuscript was improved substantially by the helpful reviews of Professor David J. Batten, University of Wales, U.K. and an anonymous referee.

진안분지 산수동층 (전기 백악기)의 유기질 미화석상

이상헌* · 윤혜수* · 이종덕**
*충남대학교 지질학과 **전북대학교 지구환경과학과

요 약 : 진안분지 산수동층에서 포자, 화분 미화석 연구가 수행되었으며, 그 결과 보존상태가 불량한 수종의 양치식물에 속하는 포자가 처음으로 보고되었다. 유기질 미화석상(palynofacies)은 주로 이지성인 식물파편, 특히 흑색의 불균형 혹은 길쭉한 타원형(elongate) 나무줄기 조각과 나뭇잎의 조각들로 구성되었다. 생물현미경하에서 포자와 식물성 조각들의 색깔은 유기물이 200℃ 이상의 온도에서 열변질 받은 것으로 나타났다. 이들의 화석상(palynofacies)은 Batten(1996)의 열변질지수 7과 직접적으로 대비된다. 즉 이것은 진안분지발달 후 우양이동 단층파쇄대(right-lateral fault fracture zone)를 따라서 마그마의 관입과 분출에 의한 국부적인 열변성작용을 받은 것으로 판단된다. 이지성인 육성기원의 유기질 파편(palynodebris)들의 비교적 양호한 분급과 해양지시성 화석의 비 산출로 보아 산수동층을 구성하는 퇴적물은 비교적 원거리로 운반되어 분지의 중심지역에 퇴적된 것으로 여겨진다. 포자화석과 기 발표된 자료들을 종합해 볼 때 산수동층은 시기적으로 전기 백악기의 Barremian에 속하는 것으로 판단된다.

REFERENCES

Baag, C. E. & Kwon, B. D., 1994 : Geophysical Studies on Major Faults in the Ogcheon Fold Belt: Aeromagnetic Data Interpretation on the Jinan Sedimentary Basin, Korea. *Korean Journal of Petroleum Geology*, v. 2 (1), p. 33-38.

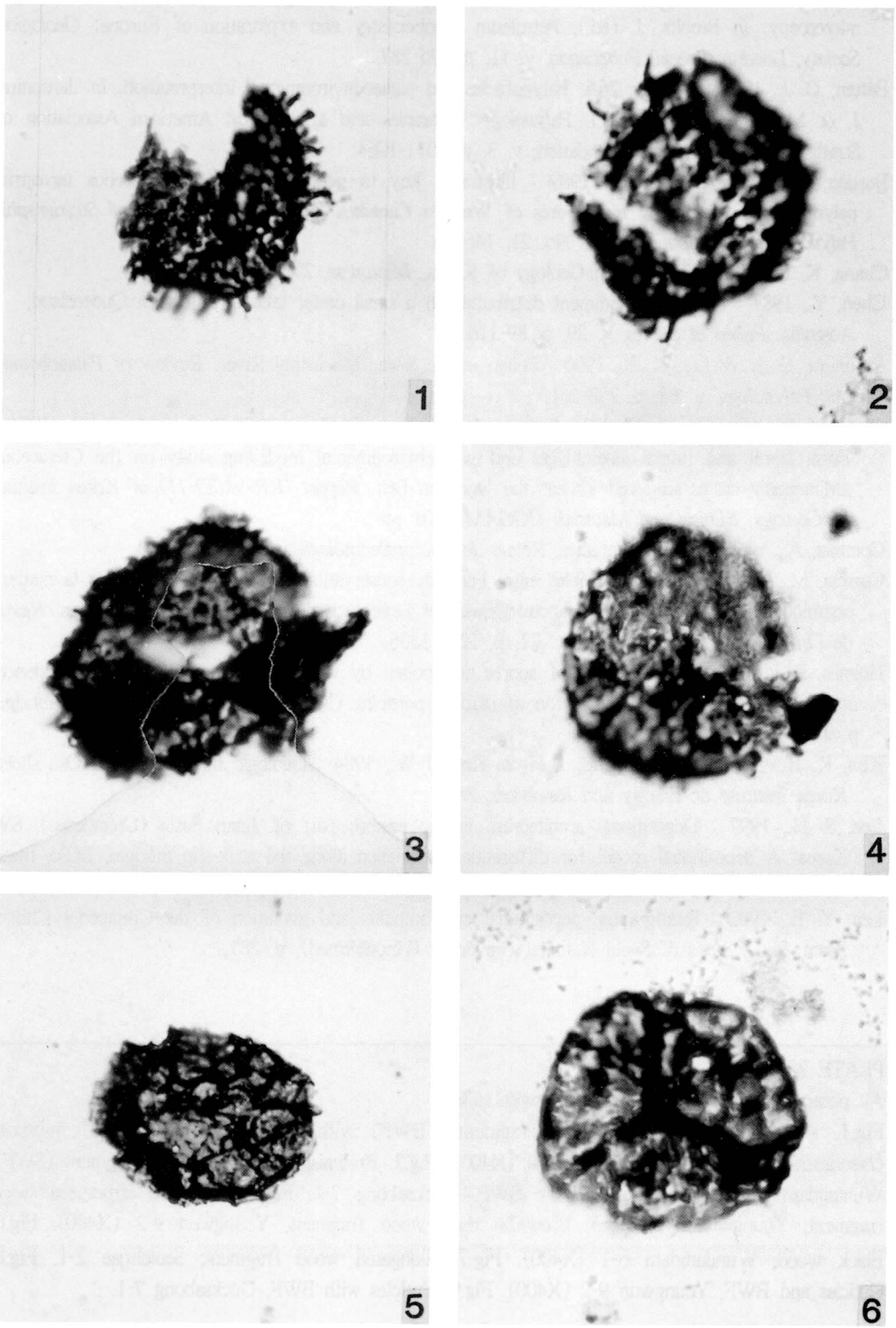
Batten, D. J., 1982 : Palynofacies, palaeoenvironments and petroleum. *Journal of Micropalaeontology*, v. 1, p. 107-114.

PLATE 1

All photographs are X800 unless otherwise stated. Specimens are identified by sample/slide number and "England Finder" reference.

Fig.1. *Neoraistrickia truncata*, Youngwun 9-2, G49/3. Fig.2. *Neoraistrickia* sp., Youngwun 9-2, K15. Fig.3. *N.* sp., Baechi 4-1, H24/1. Fig.4. *N.* sp., Youngwun 9-2, N32, proximal view. Fig.5. *Reticulatisporites semireticulatus*, Youngwun 9-2, N45/2 (X600). Fig.6. *Klukisporites southeyensis*, Youngwun 9-2, J23/4 (proximal view).

PLATE 1



Batten, D. J., 1983 : Identification of amorphous sedimentary organic matter by transmitted light microscopy. *In* Brooks, J. (ed.), Petroleum geochemistry and exploration of Europe; *Geological Society, London, Special Publication*, v. 11, p. 275-287.

Batten, D. J., 1996 : Chapter 26A. Palynofacies and palaeoenvironmental interpretation. *In*: Jansonius, J. & McGregor, D. C. (eds.), *Palynology: principles and applications*; American Association of Stratigraphic Palynologists Foundation, v. 3, p. 1011-1064.

Burden, E. T. & Hills, L. V., 1989 : Illustrated key to genera of Lower Cretaceous terrestrial palynomorphs (Excluding megaspores of Western Canada). *American Association of Stratigraphic Palynologists Contribution Series* No. 21, 146 pp.

Chang, K. H., 1985 : Treatise on Geology of Korea. *Minum-sa*, 270 pp.

Chen, Y., 1987 : Pollen and sediment distribution in a small crater lake in Northeast Queensland, Australia. *Pollen et Spores*, v. 29, p. 89-110.

Chumura, G. L. & Liu, K. B., 1990 : Pollen in the lower Mississippi River. *Review of Palaeobotany and Palynology*, v. 64, p. 253-261.

Chun, H. Y., Choi, Y. S., Choi, S. J., Kim, Y. B., Kim, B. C., Lee, B. S. & Bong, P. Y., 1994 : Fossil floral and faunal assemblages and paleoenvironmental modelling study on the Cretaceous sedimentary basins scattered in/near the Ogcheon Belt. *Report (KR-94(T)-11) of Korea Institute of Geology, Mining and Materials (KIGAM)*, 101 pp.

Combaz, A., 1964 : Les palynofacies. *Revue de Micropaleontologie*, v. 7, p. 205-218.

Correia, M., 1967 : Relations possibles entre l'etat de conservation des elements figures de la matiere organique (microfossiles palynoplanctologiques) et l'existence de gisements d'hydrocarbures. *Revue de l'Institut Francais du Petrole*, v. 22, p. 1285-1306.

Holmes, P. L., 1994 : The sorting of spores and pollen by water: experimental and field evidence. *In*: Traverse, A. (ed.), *Sedimentation of organic particles*. Cambridge University Press, Cambridge, p. 9-32.

Kim, K. B., Choi, W. C., Whang, J. H. & Kim, J W., 1984 : Geologic map of Korea, Osu sheet. *Korea Institute of Energy and Resources*, 38p.

Lee, S. H., 1997 : Depositional architecture in the eastern part of Jinan Basin (Cretaceous), SW Korea: A depositional model for differential subsidenced along the strik-slip marigin. M.Sc. thesis of Seoul National University (Unpublished), p. 147.

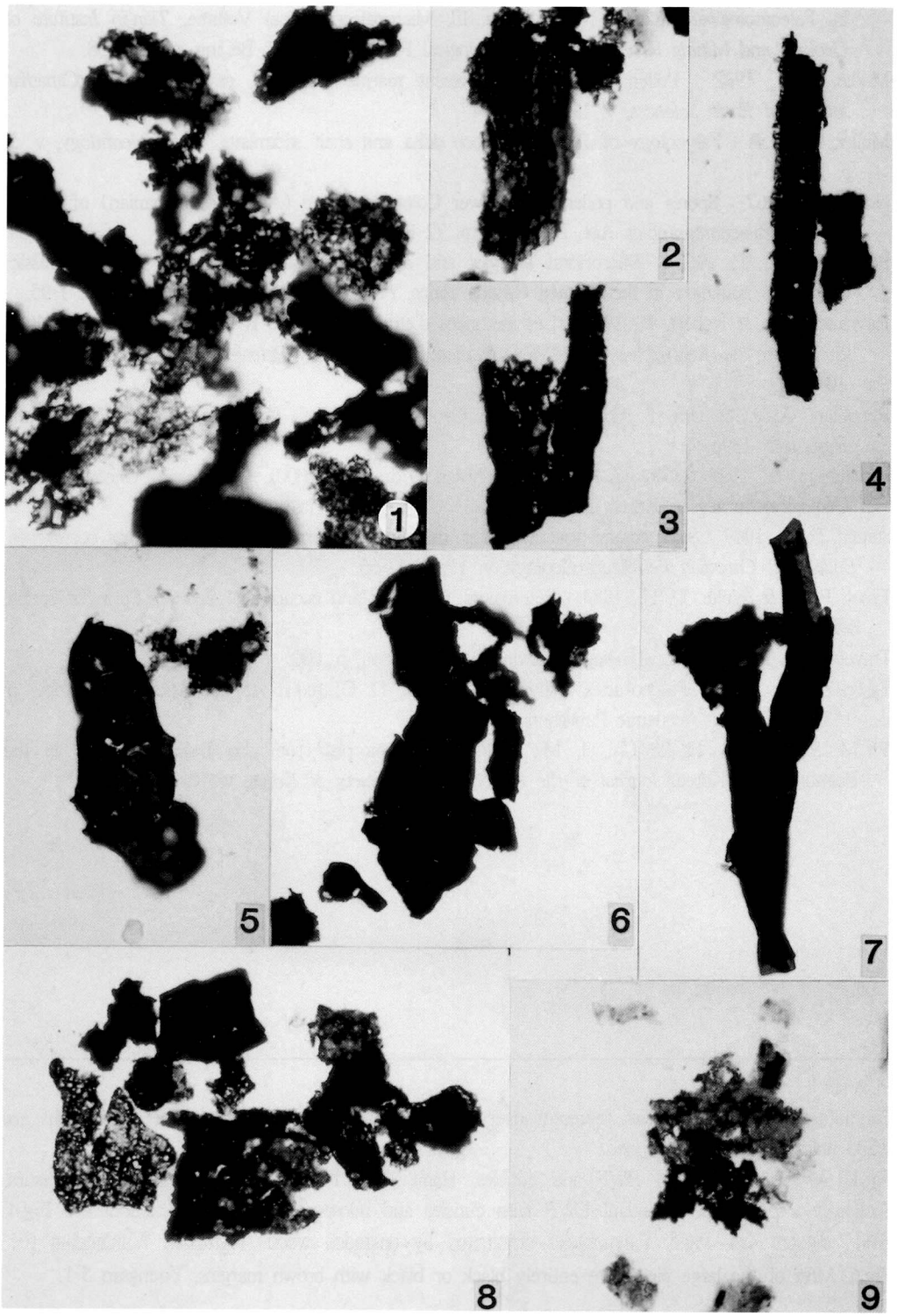
Lee, Y. E., 1992 : Stratigraphy, depositional environments and evolution of the Cretaceous Chinan Basin. Ph.D. thesis of Seoul National University (Unpublished), p. 287.

PLATE 2

All photographs are X200 unless otherwise stated.

Fig.1. Abundant large black wood fragments (BWF) with other plant tissues and miospore (*Neoraistrickia truncata*), Deockchon 1-4 (X400). **Fig.2.** Brownish structured wood fragment (SWF), Wunamdam 6-1 (X400). **Fig.3.** Dark SWF, Gucksabong 7-1. **Fig.4.** Elongated structured wood fragment, Youngwun 9-2. **Fig.5.** Brownish dark wood fragment, Youngwun 9-2 (X400). **Fig.6.** Black wood, Wundamdam 6-1 (X400). **Fig.7.** Elongated wood fragment, Seolchijae 2-1. **Fig.8.** Cuticles and BWF, Youngwun 9-2 (X400). **Fig.9.** Cuticles with BWF, Gucksabong 7-1.

PLATE 2



Miao, S., Yu, J., Qu, L., Zhang, W., Zhang, Q. & Zhang, D., 1984 : Mesozoic spores and pollen. In: Paleontological Atlas of North China, III. Micropaleontological Volume, *Tianjin Institute of Geology and Mining Research edition*, Geological Publishing House, Beijing, p. 440-638.

Mudie, P. J., 1982 : Pollen distribution in Recent marine sediments, eastern Canada. *Canadian Journal of Earth Sciences*, v. 19, p. 729-747.

Muller, J., 1959 : Palynology of Recent Orinoco delta and shelf sediments. *Micropaleontlogy*, v. 5, p. 1-32.

Norris, G., 1967 : Spores and pollen from lower Colorado Group (Albian-?Cenomanian) of central Alberta. *Palaeontographica Abt. B*, v. 120, p. 72-115.

Pocock, S. A. J., 1962 : Microfloral analysis and age determinations of strata at the Jurassic-Cretaceous boundary in the western Canada plains. *Palaeontographica Abt. B*, v. 111, p. 1-95.

Raynaud, J. F. & Robert, P., 1976 : Les methodes d'etude optique de la matiere organique. *Bulletin du Centre de Recherches Pau-SNPA (Societe Nationale des Petroles d'Aquitaine)*, v. 10, p. 109-127.

Reedman, A. J. & Um, S. H., 1975 : The Geology of Korea. *Korea Institute of Energy and Resources*, 139p.

Shimamura, S., 1925 : Geological Atlas of Chosen (Korea; 1:50,000). Chinan and Cheonju sheets. Geological Survey of Korea, No. 5.

Staplin, F. L., 1969 : Sedimentary organic matter, organic metamorphism, and oil and gas occurrence. *Bulletin of Canadian Petroleum Geology*, v. 17, p. 47-66.

Tissot, B. P. & Welte, D. H., 1984 : Peteroleum formation and occurrence; 2nd ed. Springer-Verlag, Berlin, 699 pp.

Traverse, A., 1988 : Paleopalynology. Unwin Hyman, Boston, p. 600.

Tyson, R. V., 1993 : Palynofacies analysis. *In* Jenkins, D. G. (ed.), *Applied Micropaleontology*, p. 153-191. Kluwer Academic Publishers.

Yi, M. S., Cho, B. H. & Chi, J. M., 1994 : Palynomorphs from the Jinju Formation in the Euiseong area, Korea. *Journal of the Paleontological Society of Korea*, v. 10, p. 41-56

PLATE 3

Palynofacies. The palynofacies represent over-mature organic phytoclast facies. All photographs are X200 unless otherwise mentioned.

Fig.1. Abundant elongated BWF and cuticles, Hanil 10-5. **Fig.2.** BWF and other plant tissues, Seolchijae 2-20. **Fig.3.** Abundant BWF with cuticles and miospore (arrow), Deuckchon 1-4. **Fig.4.** BWF, Seulchi 4-5. **Fig.5.** Palynofacies dominated by degraded wood fragments, Wunamdam 6-1. **Fig.6.** Most of the large pieces are entirely black or black with brown margins, Youngsan 5-1.

PLATE 3