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The Vegetational and Environmental History of the Pre-Holocene Period in the Korean Peninsula

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韓半島 植生 및 環境變遷史(홀로世 以前 時代를 中心으로)

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ABSTRACT

The reconstruction of the vegetational and environmental history of the Korean peninsula by the use of various fossil floral data from the Carboniferous period to the Pre-Holocene is reviewed.

Though the oldest plant fossil in Korea (*Neuropteris*) dates back to the Carboniferous period, the first appearance of many of the present-day floristic genera indeed dates back to the Oligocene (*c.* 40 to 20 million years B.P.), and includes many thermophilous genera. The presence of thermophilous genera in the Oligocene at up to four degrees north of their present distributional limits implies that the climate of the Oligocene was warmer than that of today.

The occurrence of similar thermophilous floristic element at up to six degrees north of their present range during the Middle Miocene suggests a maximum northward expansion of warmth-loving evergreen broadleaved vegetation for recent Korean vegetation history. The continued occurrence of numerous present-day genera since the Oligocene period indicates a long-term stability of Korean vegetation, along with minor fluctuations within it.

The admixture of evergreen coniferous plants and deciduous breadleaved plants, however, indicates a probable temperate climate for much of the Middle Pleistocene. There are couple of evidences which are indicative of an early-stage anthropogenic disturbance of natural vegetation during the Middle Pleistocene of Korea.

The presence of cold-episodes during the Upper Pleistocene caused a general expansion of deciduous plants and cryophilous evergreen coniferous plants. It is likely that the maximum southward expansion of cryophilous arctic-alpine and alpine floras

in Korea occured during the penultimate glacial period. The disappearance of some cryophilous genera from 10,000 years B.P. marks the continued climatic amelioration since then, along with minor climatic fluctuations during the Holocene period.

要 約

本 硏究는 石炭紀 이래 플라이스토世 末期까지 韓半島가 겪어온 植生史와 環境史를 時系列的으로 分析한 것으로 植物化石 資料가 주로 利用되었다.

韓半島에서 發見된 最古의 植物化石은 古生代 石炭紀에 출현한 *Neuropteris* 이지만 우리가 오늘날 볼 수 있는 植物相의 原形은 新生代 올리고世부터 발견되었다. 특히 올리고世에는 暖地를 選好하는 常綠闊葉樹가 오늘날에 비해 緯度上으로 4°정도 北上했던 사실로 미루어 당시의 氣候는 오늘날보다 温暖했던 것으로 간주된다.

마이오世 中期에는 暖地를 選好하는 常綠闊葉樹가 現在의 分布域에 비해 6°정도 北으로 진출했던 것으로 나타났다. 즉 마이오世 中期는 新生代 以來 韓半島에서 暖地選好 植生이 최대로 北上했던 때이고 氣候 또한 가장 温暖했던 시기임을 암시한다.

플라이스토世 中期에 韓半島는 常綠針葉樹와 落葉闊葉樹가 混在하는 温帶氣候가 나타났으며 人間에 의해 植生이 간섭받은 흔적이 부분적으로 나타난다. 플라이스토世 末期에는 寒地選好 極地-高山植物과 高山植物들의 分布域이 新生代 이래 韓半島 植生史上 가장 南下했던 때로 당시의 氣候는 寒冷했던 것으로 사료된다. 플라이스토世가 끝나는 10,000年前 부터 寒地選好 植生은 점차 감소하여 氣候 温暖化 傾向이 나타난다.

INTRODUCTION

Aims and Data

The essential objectives of this review include the reconstruction of the vegetational and environmental history of the Korean peninsula, from the Carboniferous period to the Pre-Holocene, *i.e.* 10,000 years B.P.

For the reconstruction and interpretation of past vegetational patterns, numerous fossil floral data have been collated and presented chronologically. These have been classified into three major periods, *i.e.* the Palaeozoic, the Mesozoic and the Cenozoic Eras. Pre-historic vegetational sources considered come mainly from macro- and micro-fossils of flora (Huzioka, 1951, 1972; Yasuda *et al,* 1980; KIER, 1982; Park, 1983; Sohn, 1984; Chang, 1985; Lee, 1987; Kim & Hong, 1991). The scattered nature of the data, however, makes most interpretation qualitative rather than quantitative.

The boundary of each geological phase is based on the time-scales adopted by Holmes (1978). Pre-Pleistocene fossil sites in the Korean peninsula are presented in Figure 1.

The collected floral data are to be presented chronologically, using as a base schema produced by Lee(1987), as displayed in Table 1.

VEGETATION OF THE PALAEOZOIC ERA (*c.* 600 to 225 my. B.P.)

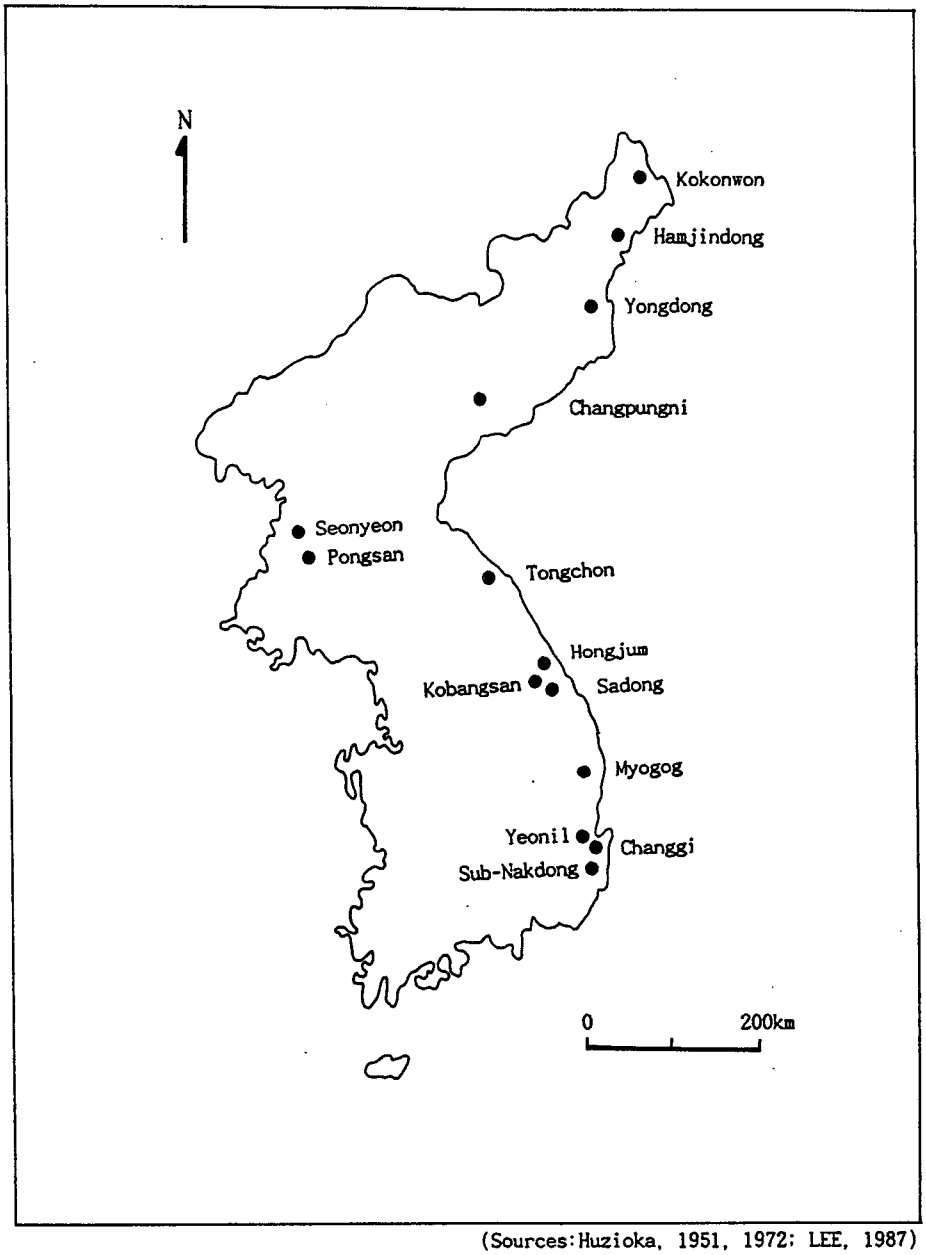

Fig. 1. Pre-Pleistocene Fossil Sites in Korea

In the case of the Korean peninsula, there is no relevant information available prior to the Carboniferous period. The oldest plant fossil in Korea (*Neuropteris*) dates back to the Carboniferous period (Lee, 1987).

1. Carboniferous Period (*c*, 350 to 270 my. B.P.):

Plant macrofossils of four genera are present in the Hongjum layer of the Korean Carboniferous, *viz*, *Lepidodendron*, *Neuropteris*,

Table 1. Chronology of Korea

Geologic Period			Stratigraphy
Era	Period		Layer
Cenozoic	Quaternary	Holocene	Lake Younglang
		Pleistocene	Lake Younglang, Hwadae, Sokchang-ni
			Turubong, Chummal Yonggul
			Haesang, Chongjongam
			Turubong, Chummal Yonggul
			—
	Tertiary	Pliocene	Seoguipo
		Miocene	Yeonil, Hamjindong
			Kokonwon, Changgungni, Tongchon
			Yongdong, Changgi
		Oligocene	Pongsan
		Eocene	—
		Palaeocene	—
Mesozoic	Cretaceous		Sub-Nakdong
	Jurassic		Myogog
			Seonyeon
	Triassic		Kobangsan
Palaeozoic	Permian		Sadong
	Carboniferous		Hongjum

(Compiled from Huzioka, 1951, 1972; Yoo, 1970; Kim, 1980; Yasuda *et al.* 1980; Choi, 1983, 1986; Park, 1983; Sohn, 1984; Lee, 1987).

Linopteris and *Odontopteris*.

In this period climates were relatively warm all over the world, though they became somewhat colder in the Upper Carboniferous period (Chaloner & Meyen, 1973; Dickins, 1984).

2. Permian Period (*c.* 270 to 225 my. B.P.):

About 112 species of plant macrofossils have been described from the Sadong layer of the Korean Permian, among which are representatives of the following groups: Equisetales (15 spp.), Sphenophyllales (10 spp.), Filicales and Pteridospermae (54 spp.), Lycopodiales (8 spp.), Psilotales (6 spp.), Cordaitales (9 spp.), Cycadophyta (4 spp.), Ginkgoales (3 spp.), Con-

iferales (5 spp.), Semina Gymnospermae (8 spp.) and Plantae Incretae Sedis (4 spp.).

The dominance of ferns and gymnospermae, and the presence of a relatively rich flora, suggest that the local climates had started to warm up again after the relative cool phase of the Upper Carboniferous.

VEGETATION OF THE MESOZOIC ERA (*c.* 225 to 70 my. B.P.)

1. Triassic Period (*c.* 225 to 180 my. B.P.):

The Kobangsan layer of the Upper Permian and Lower Triassic is dominated by Filicales and Pteridospermae (20 spp.), along with Equisetales (9 spp.), Sphenophyllales (6 spp.), Lycopodiales (2 spp.), Psilotales (2 spp.), Cordaitales (2 spp.), Coniferales (1 sp.) and Plantae Incertae Sedis (11 spp.). This suggests the existence of a further relatively warm and humid climate.

2. Jurassic Period (*c.* 180 to 135 my. B.P.):

120 species of plant macrofossils have been located in the Seonyeon layer of the Upper Triassic and Lower Jurassic, *viz.* Filicales and Pteridospermae (32 spp.), Ginkgoites and Ginkgoales (23 spp.), Equisetales (15 spp.), Bennettitales (13 spp.), Cycadales (10 spp.), Coniferales (15 spp.), and Plantae Incertae Sedis (12 spp.).

From the Upper Jurassic ten species are present within the Myogog layer, *viz. Cladophebis* (3 spp.), *Adiantites* (1 sp.), *Onychyopsis* (2 spp.), Equitites (1 sp.), Ginkgoales (1 sp.), *Nilssonia* (1 sp.) and Podozamites (1 sp.). The presence of ferns and gymnospermae again suggests relatively warm and humid climate.

3. Cretaceous Period (*c.* 135 to 70 my. B.P.):

70 species have been described for the Sub-Nakdong layer of the Lower Cretaceous, *viz.* Filicales and Pteridospermae (17 spp.), Equisetales (3 spp.), Bennettitales (9 spp.), Nilssoniales (4 spp.), Baiera (1 sp.), *Ginkgo* (2 spp.), Ginkgodium (2 spp.), Coniferales (7 spp.) and Plantae Incerte Sedis (5 spp.). The Cretaceous period contains the oldest plant fossil of present-day floristic element in Korea, *i.e. Ginkgo.* No dramatic climatic change from that of previous periods is envisaged.

VEGETATION OF THE CENOZOIC ERA (*c.* 70 my. B.P. to Present)

1. Palaeocene - Eocene Period (*c.* 70 to 40 my. B.P.):

In the Korean peninsula, no floristic fossil data are available for these two periods.

2.Oligocene Period (*c.* 40 to 25 my. B.P.):

The macrofossils of 18 broadleaved plants, *viz. Populus* (3 spp.), *Myrica* (1 sp.), ? *Juglans* (1 sp.), *Ficus* (2 spp.), *Platanus* (3 spp.), ? *Credneria* (1 sp.), *Celastrus* (1 sp.), *Acer* (1 sp.), *Sapindus* (1 sp.), *Zizyphus* (1 sp.), *Hedera* (1 sp.) and *Viburnum* (2 spp.) have been identified in the Pongsan layer of the Oligocene. The appearance of such relatively thermophilous genera at *c.* 38°30′N, along with a comparison of the present-day northern limits of these genera, *viz. Myrica* at 34°30′N, *Ficus* at 35° N and *Hedera* at 37°30′N, is indicative of the fact that the Oligocene climate was somewhat warmer than today, to the extent that evergreen broadleaved genera were able to reach the latitude they did.

3. Miocene Period (*c.* 25 to 12 my. B.P.):

In the Lower Miocene, the Changgi layer displays three ferns, five conifers and 36 dicotyledons, *viz. Pteridium* (1 sp.), *Polypodites* (1 sp.), *Salvinia* (1 sp.), *Picea* (1 sp.), *Pseudotsuga* (1 sp.), *Glyptostrobus* (1 sp.), *Metasequoia* (1 sp.), *Sciadoptitys* (1 sp.), *Salix* (1 sp.), *Platycarya* (1 sp.), *Pterocarya* (1 sp.), *Betula* (3 spp.), *Carpinus* (4 spp.), *Ostrya* (1 sp.), *Fagus* (1 sp.), *Quercus* (1

sp.), *Ulmus* (1 sp.), *Zelkova* (1 sp.), *Hydrangea* (1 sp.), *Magnolia* (2 spp.), *Sorbus* (2 spp.), *Cladrastis* (1 sp.), *Rhus* (1 sp.), *Acer* (5 spp.), *Aesculus* (1 sp.), *Tilia* (1 sp.), *Alangium* (1 sp.), *Hemitrapa* (1 sp.), *Cornus* (1 sp.), *Rhododendron* (1 sp.), *Diospyros* (1 sp.), *Fraxinus* (1 sp.) and *Viburnum* (1 sp.).

Only 25 genera (80%) of this Lower Miocene flora of Korea still have representatives in the Korean peninsula, but 29 genera (94%) may be seen in the Japanese Islands. The dominance of deciduous broadleaved plants suggests the existence of a temperate climate at this time.

Another Lower Miocene flora (the Yongdong layer) consists of 12 families and 15 genera, *viz. Picea* (1 sp.), *Glyptostrobus* (1 sp.), *Metasequoia* (1 sp.), *Pterocarya* (1 sp.), *Betula* (1 sp.), *Carpinus* (1 sp.), *Ostrya* (1 sp.), *Fagus* (1 sp.), *Zelkova* (1 sp.), *Cercidiphyllum* (1 sp.), *Rosa* (1 sp.), *Acer* (4 spp.), *Aesculus* (1 sp.), *Tilia* (4 spp.) and *Alangium* (1 sp.). All of these were recorded in the Changgi flora as well, with the exception of *Cercidiphyllum* and *Rosa*. Overall, the evidence suggests that northern Korea (Yongdong) and southern Korea (Changgi) together were under similar temperate climatic conditions at this time.

Twenty species were presented in the Tongchon flora of the Middle Miocene, *viz. Pinus* (1 sp.), *Glyptostrobus* (1 sp.), *Metasequoia* (1 sp.), *Populus* (1 sp.), *Salix* (2 spp.), *Comptonia* (1 sp.), *Pterocarya* (1 sp.), *Alnus* (1 sp.), *Betula* (1 sp.), *Fagus* (1 sp.), *Zelkova* (1 sp.), *Cercidiphyllum* (1 sp.) *Acer* (5 spp.), *Hemitrapa* (1 sp.) and *Alangium* (1 sp.). The admixture of conifers and deciduous broadleaved plants again suggests a temperate climate.

Also from the Middle Miocene, ten species have been described from Changpungni flora, *viz. Glyptostrobus* (1 sp.), *Salix* (1 sp.), *Comptoniphylla* (1 sp.), *Juglans* (1 sp.), *Carpinus* (1 sp.), *Fagus* (1 sp.), *Cinnamomum* (1 sp.), *Prunus* (1 sp.), *Acer* (1 sp.) and *Rhamnus* (1 sp.). The most significant feature here, perhaps, is the appearance of the evergreen broadleaved species, *Cinnamomum*, which is indicative of a slightly warmer climate in this locality as compared to that of today.

Another Middle Miocene flora (the Kokonwon layer) contains 21 families 30 genera and 41 species, *viz. Salvinia* (1 sp.), *Keteleeria* (1 sp.), *Pseudotsuga* (1 sp.), *Glyptostrobus* (2 spp.), *Metasequoia* (1 sp.), *Sciadopitys* (1 sp.), *Calocedrus* (1 sp.), *Thujopsis* (1 sp.), *Salix* (1 sp.), *Engelhardtia* (1 sp.), *Alnus* (1 sp.), *Betula* (2 spp.), *Carpinus* (1 sp.), *Castanea* (1 sp.), *Fagus* (4 spp.), *Quercus* (3 spp.), *Cyclobalanopsis* (2 spp.), *Zelkova* (1 sp.), *Nelumbo* (1 sp.), *Cercidiphyllum* (1 sp.), *Liriodendron* (1 sp.), *Platanus* (1 sp.) *Gleditia* (1 sp.), *Ilex* (1 sp.), *Euonymus* (1 sp.), *Acer* (4 spp.), *Vitis* (1 sp.), *Kalopanax* (1 sp.), *Porana* (1 sp.) and *Alangium* (1 sp.). The apperance of the evergreen broadleaved plants *Cyclobalanopsis* and *Ilex* in northern Korea (Kokonwon, *c.* 42° N) and neighbouring Changpungni suggests the presence of a major climatic amelioration at this time, in which occurred possibly the maximum northward expansion of evergreen broadleaved vegetation in Korean vegetation history, for these genera then exist some 6 degrees of latitude further to the north than they do today.

In the Upper Miocene, the Hamjindong layer in the north comprises 23 families, 31 genera and 48 species, *viz. Equisetum* (1 sp.), *Dryopteris* (1 sp.), *Picea* (2 spp.), *Glyptostrobus* (1 sp.), *Metasequoia* (1 sp.), *Populus* (1 sp.), *Juglans* (1 sp.), *Pterocarya* (2 spp.), *Alnus* (1 sp.), *Carpinus* (2 spp.), *Fagus* (3 spp.), *Ulmus* (2 spp.), *Zelkova* (1 sp.), *Cercidiphyllum* (1 sp.), *Liriodendron* (1 sp.), *Lindera* (1 sp.), *Sassafras* (1 sp.), *Platanus* (1 sp.), *Hamamelis* (1 sp.), *Liquidambar* (1 sp.), *Parrotia* (1 sp.), *Prunus* (1 sp.), *Cercis* (1 sp.), *Acer* (11 spp.), *Aesculus* (1 sp.), *Tilia* (2 spp.), *Rhododendron* (2 spp.), *Diospyros* (1 sp.), *Styrax*

(1 sp.) and *Fraxinus* (1 sp.).

In the south, another Upper Miocene flora (the Yeonil layer) contains 17 families, 27 genera and 32 species, *viz. Pinus* (1 sp.), *Keteleeria* (1 sp.), *Sciadopitys* (1 sp.), *Pterocarya* (1 sp.), *Carpinus* (3 spp.), *Castanea* (1 sp.), *Fagus* (1 sp.), *Castanopsis* (1 sp.), *Cyclobalanopsis* (3 spp.), *Lidera* (1 sp.), *Phoebe* (1 sp.), *Passania* (2 spp.), *Zelkova* (1 sp.), *Cinnamomum* (1 sp.), *Cryptocarya* (1 sp.), *Platanus* (1 sp.), *Liquidambar* (1 sp.), *Parrotia* (1 sp.), *Entada* (1 sp.), *Acer* (1 sp.), *Sapindus* (1 sp.), *Paliurus* (1 sp.), *Alangium* (1 sp.), *Hemitrapa* (1 sp.), *Rhododendron* (1 sp.), *Fraxinus* (1 sp.) and *Carpites* (1 sp.).

The presence of such a relatively rich flora, in which are the evergreen broadleaved plants, *viz. Castanopsis, Cyclobalanopsis* and *Cinnamomun,* suggest the continuation in this district of a warm climate. However, the absence of these indicator species at Hamjindong suggests that some significant cooling had already begun in the north.

Overall, ten genera occur continuously from the Lower Miocene to the Upper Miocene in the Korean peninsula as a whole, namely *Glyptostrobus, Metasequoia, Pterocarya, Carpinus, Fagus, Zelkova, Acer, Alangium, Hemitrapa* and *Cercidiphyllum.* Out of these *Carpinus, Fagus, Zelkova, Acer* and *Alangim* are still growing naturally in present-day Korea.

The intermittent occurrence of numerous other representatives of the present-day flora from the Oligocene and within the Miocene periods also suggest that they were a stable feature of Korean vegetation, ensuring its continuity over a long period of time. Among these latter are *Picea, Pinus, Populus, Salix, Myrica, Juglans, Platycarya, Carpinus, Ostrya, Alnus, Betula, Ficus, Celastrus, Castanopsis, Castanea, Cyclobalanopsis, Fagus, Quercus, Ulmus, Zelkova, Nelumbo, Hydrangea, Magnolia, Cinnamomum, Sorbus, Rosa, Prunus, Cladrastis, Rhus, Acer, Ilex, Euonymus, Sapindus, Paliurus, Rhamnus, Vitis, Tilia, Kalopanax, Alangium, Cornus, Rhododendron, Fraxinus, Styrax, Viburnum, Equisetum and Dryopteris.*

In summary, one may say that the temperate climate of the Lower Miocene of Korea subsequently became ever milder in the Middle Miocene, but later during the Upper Miocene, regional differences in vegetation type and climate began to occures, as temperatures in the north were lowered relative to those in the south.

4. Pliocene Period (*c.* 12 to 3 my. B.P.):

No floristic fossil data are available for Korea from this period.

5. Pleistocene Period (*c.* 3 my to 10,000 yrs. B.P.):

An almost total lack of data from the Lower Pleistocene in Korea means that only the Middle and Upper Pleistocene are considered herein. The Middle and Upper Pleistocene human-occupied sites in the Korean peninsula are presented in Fig. 2.

1) Middle Pleistocene (*c.* 700,000 to 110,000 yrs. B.P.):

Middle Pleistocene floral macro- and microfossils have been collected from only two Early Palaeolithic sites, *viz.* Sangwon Kumunmoru cave and Chewon Chummel Yonggul cave. No absolute dating is available for any of these sites.

In Sangwon Kumunmoru cave, charcoal of *Pinus* has been recorded. Arboreal pollens of Juglandaceae, *Pinus* and *Thuja,* and non-arboreal pollen of *Equisetum* are present.

In Chewon Chummal Yonggul cave seeds of Juglandaceae, *Celtis* and leaves of *Benzoin obtusilobum* have been founded. Arboreal pollens of Aquifoliaceae, *Betula, Castanea, Fagus, Quer-*

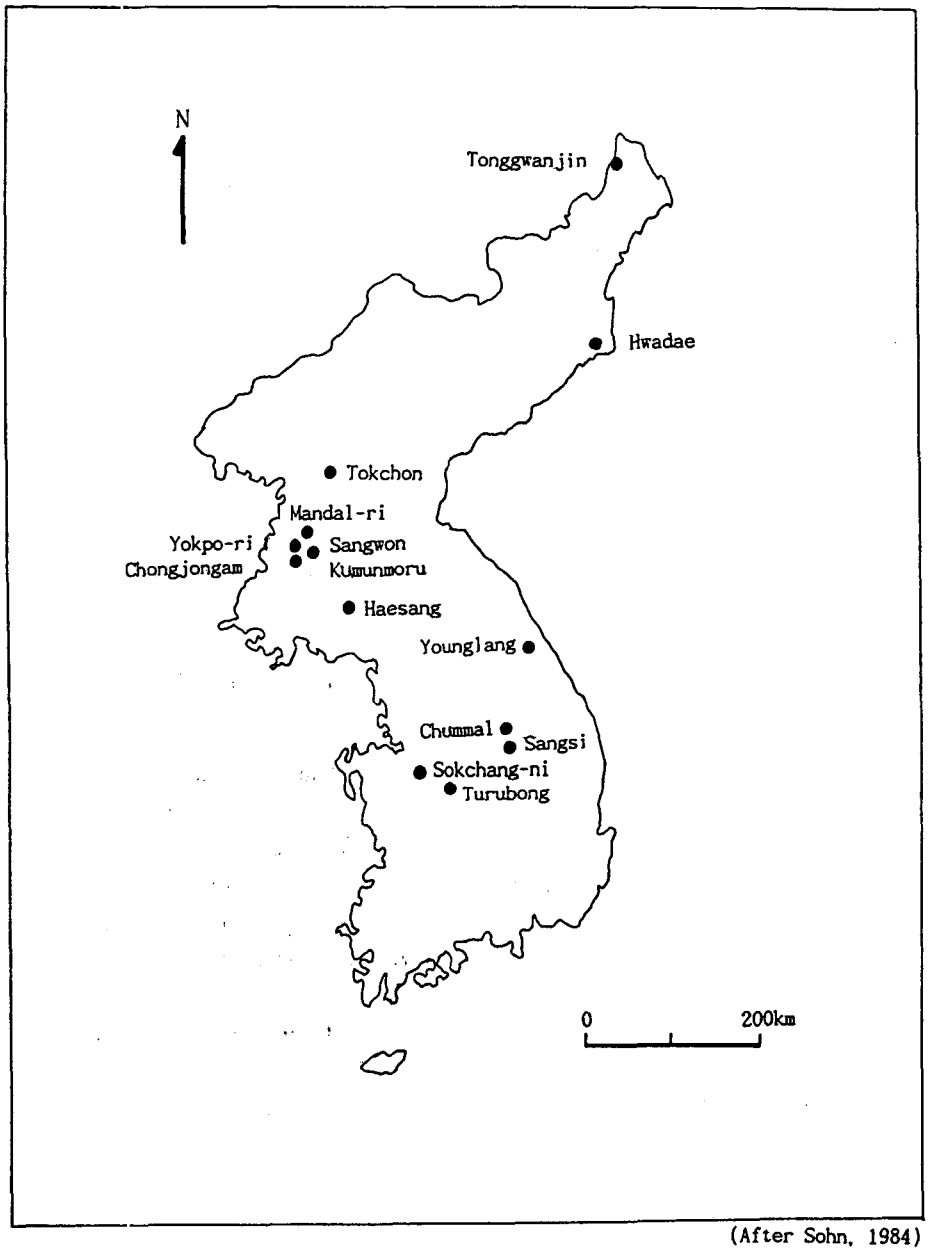

Fig. 2. Middle and Upper Pleistocene Human-occupied Sites in Korea

cus, Salix, Tilia, Taxus, Abies, Pinus and non-arboreal pollen of *Artemisia* are present.

From these data it is clear that many deciduous broadleaved plants and evergreen coniferous plants were present in the Korean peninsula for at least part of this period. Also, the appearance of *Pinus* charcoal in the cave suggests that some anthropogenic disturbance of natural vegetation was taking place during this period. The existence of many present-day floristic elements indicates that climate was not very much differeat from today.

2) Upper Pleistocene (*c.* 110,000 to 10,000 yrs. B.P.):

Upper Pleistocene floral macro- and micro-fossils have been collected from six sites.

In Sangwon Chongjongam cave, pollen of Pteridaceae, *Juglans* sp. and *Thuja* are present.

In Pyongsan Haesang cave, pollen of *Abies, Pinus, Osmunda* and Pteridaceae has been founded.

In Chewon Chummal Yonggul cave, leaves of *Smilax china* var. *macrophylla,* charcoal of *Sambacus,* Prunoideae, Papilionoidae, *Prunus,* Elaeagnaceae, Araliaceae, Fagaceae, Taxaceae, *Pinus* and Cupressaceae, and seeds of Juglandaceae and *Celtis* are present. In the same place, arboreal pollen of Aquifoliaceae, *Alnus, Betula, Carpinus, Castanea, Fagus, Quercus,* Juglandaceae, Lauraceae, *Populus, Salix, Tilia, Taxus, Abies, Larix* and *Pinus* are present, along with four non-arboreal pollens, *viz. Chenopodium, Artemisia, Drosera* and Gramineae.

In Chongwon Chummal Yonggul cave seeds Fagaceae, *Pinus* and Aceraceae have been recorded, along with arboreal pollen of Aceraceae, *Alnus, Betula, Carpinus, Quercus, Ligustrum, Tilia, Taxus, Abies, Larix* and *Pinus.* Non-arboreal pollen of *Artemisia,* Gramineae, Cyperaceae, *Typha,* Scrophulariaceae and Compositae are also present.

In Kongju Sokchangni cave, arboreal pollen of Aceraceae, *Alnus, Betula,* Magnoliaceae, Nymphaceae, *Ligustrum, Abies and Pinus* as well as non-arboreal pollen of Lycopodiaceae, Cyperaceae and Liliaceae have been founded.

Upper Pleistocene site in Hwadae peat layer contains arboreal pollen of *Alnus, Betula, Salix, Abies, Larix, Picea, Pinus, P. koraiensis, P. pumila, P. sibirica* and *Juniperus dahurica,* along with non-arboreal pollen of *Saxifraga, Oxytropis,* Bryales, *Sphagnum,* Iridiaceae, *Urtica,* Gramineae, Cyperaceae, Compositae and *Osmunda.* The occurrence of cryophilous *Pinus koraiensis, P. pumila, P. sibirica, Juniperus dahurica, Abies, Picea, Pinus* (Haploxylon), *Saxifraga* and *Oxytropis* indicates the existence of at this time of a rich floristic association, but also a cold climate.

Of vegetation changes subsequent to the Last Glacial Maximum, little is known, though the bore-hole sample from Lake Younglang (128°35′ E, 38°12′ N) is of importance, since it contains pollen grains and an absolute ^{14}C dating record which is of 17,000 years B.P. (Yasuda *et al,* 1980).

An interpretation of its data suggests that from 17,000 to 15,000 years B.P., cryophilous coniferous trees, *e.g. Picea, Larix, Abies* and *Pinus* (Haploxylon), were dominant in this region with a large amount of open-land *Artemisia* and hydrophilous Cyperaceae. Smali amount of *Tilia, Quercus,* Gramineae, Umbelliferae and Chenopodiaceae also were present.

Then, from 15,000 to 10,000 years B.P., as the climate ameliorated, the coniferous tree elements decline in abundance, and were replaced largely by deciduous broadleaved trees, such as *Tilia* and especially *Quercus.* There was a decrease in the number of *Artemisia* and hydrophilous Cyperaceae, and an increase in Gramineae. Other non-arboneal pollens of Oleaceae, Chenopodiaceae, Umbelliferae, Compositae and Typhaceae were also presented at this time.

DISCUSSION AND SUMMARY

Despite the general paucity of floristic fossil data some scattered macro- and micro-fossil data enable one to reconstruct the Pre-Holocene vegetational and environmental history of the Korean peninsula.

Though the oldest plant fossil of present-day floristic element in Korea (*Ginkgo*) dates back

to the Cretaceous Period (*c.* 135 to 70 my. B.P.), the first appearance of many of the present-day floristic genera indeed dates back to the Oligocene Period (*c.* 40 to 25 my. B.P.). These include thermophilous evergreen broadleaved genera, such as *Myrica, Ficus* and *Hedera* and other temperate deciduous broadleaved plants, *e.g. Populus, Juglans, Platanus, Celastrus, Acer, Sapindus, Zizyphus* and *Viburnum.* The presense of thermophilous genera at up to four degrees north of their present distributional limits implies that the climate of the Oligocene was warmer than that of today.

The warm temperate climate of the Oligocene and the Lower Miocene of Korea (*c.* 25 my. B.P.) subsequently warmed still further up to the Middle Miocene. Then, the appearance of additional thermophilous broadleaved plants, *e.g. Cinnamomum, Cyclobalanopsis* and *Ilex* in the north of the Korean peninsula during the Middle Miocene suggests a maximum northward expansion of warmth-loving vegetation for recent Korean vegetation history, these genera six degrees of latitude further to the north than they do today. A relatively rich flora, and the continued presence of thermophilous evergreen broadleaved plants in the south of the Korean peninsula, suggests the maintenance of a warm climate there in the Upper Miocene (*c.* 12 my. B.P.). The first appearance of numerous present-day floristic genera is noticed during the Miocene period and it indicates a long-term stability of Korean vegetation.

Unfortunately, from the Pliocene to the Pleistocene , no floristic fossil data are available from Korea, and so a hiatus in the vegetation data of the Korean peninsula of some considerable length then begins.

The admixture of cryophilous evergreen coniferous plants, *e.g. Taxus, Abies* and *Thuja,* along with deciduous broadleaved plants which dates back at least to the Middle Pleistocene (*c.* 700,000 to 110,000 yrs. B.P.) indicates a probable cool temperate climate for much of the Middle Pleistocene. The further occurrence of *Pinus* charcoal and *Artemisia* pollen in human-occupied caves at this time also probably suggests an early-stage anthropogenic disturbance of natural vegetation during the Middle Pleistocene of Korea.

Subsequently, the appearance of deciduous broadleaved plants and cryophilous evergreen coniferous plants, *viz. Taxus, Abies, Picea, Tsuga, Pinus* and *Thuja,* within the Korean peninsula indicates the presence of cold episodes during the Upper Pleistocene (*c.* 110,000 to 10,000 yrs. B.P.). This is examplified more particularly by the sudden appearance of cryophilous evergreen coniferous plants, such as *Pinus koraiensis, P. pumila, P. sibirica,* and species of *Tseudotsuga* and *Juniperus,* at these relatively late stages of the Upper Pleistocene. It is likely that the maximum southwards expansion of cryophilous arctic-alpine evergreen coniferous and broadleaved plants in the Korean peninsula occurred at such times in the Upper Pleistocene (Kong, 1991).

From 17,000 to 15,000 years B.P., cryophilous evergreen coniferous plants, *e.g. Picea, Abies, Pinus* (Haploxylon) were increasingly widespread. Then, a decline of evergreen coniferous plants from 15,000 to 10,000 years B.P., and the disappearace of some cryophilous genera from 10,000 years B.P. marks the continued climatic amelioration in the Holocene Period.

REFERENCES

Chaloner, W, G.& Meyen, S. V., 1973, Carboniferous and Permian flora of the northern continents. In: Halle, A. (ed.), *Atlas of Palaeo-biogeography,* 169-186, Elsevier Sci. Publ. Co. Amsterdam.

Chang, K, H., 1985, *Geology of Korea,* Minumsa, Seoul (in Korean)

Choi, M, C., 1983, Comparison of Korean Palaeolithic culture with Chinese one. In: The National History Compilation Committee (ed.), *Korean History,* Vol.12 (Korean Archaeology), 307-366, Seoul, (in Korean).

Dickins, J, M., 1984, Evolution and climate in the Upper Palaeozoic. In: Breachley, P. (ed.), *Fossils and Climate,* 317-327, John Wiley and Sons, Chichester.

Holmes, D., 1978, *Principles of Physical Geology,* Van Nostrand Reinhold (U.K) Co. 3rd Ed., Wokingham.

Huzioka, K, 1951, Notes on some Tertiary plants from Korea, *Trans, Proc. Palaeontol. Soc. Jap. N.S.,* **3,** 57-74.

Huzioka, K, 1970, The Tertiary floras of Korea, *J.Min. Coll. Akita Univ. Ser. A.,* Vol. **5,** 1-83.

KIER, 1982, *Geology of Korea,* Korea Institute of Energy and Resources, Taejon, (in Korean).

Kim, J. H. & Hong, S. S., 1991, *The History of Korean Butterflies and Origin of Japanese Endemic Butterflies.* Chiphyonsa, Seoul, (in Korean).

Kong, W. S., 1991, Present distribution of cryophilous plants and palaeoenvironment in the Korean peninsula, *Kor. Jour. Quat. Res.,* **5**(1), 1-13.

Lee, H. Y., 1987, *Palaeontology of Korea,* Minumsa, Seoul, (in Korean).

Park, H. H., 1983, Fauna and flora, In: The National History Compilation Committee. (ed.), Korean History, Vol, **12** (Korean Archaeology), 91-186, Seoul, (in Korean).

Sohn, P.K., 1984, The palaeoenvironmeat of middle and upper Pleistocene Korea. In: Whyte, R. P. (ed.), *The Evolution of the East Asian Environment,* Vol, **4,** 877-893, Univ. Hong Kong.

Yasuda, Y., Kim, J. M., Lee, S. T. and Yim, Y. J., 1980, Environmental Changes and Agricultural Origin in Korea, *Jap. Min. Educ. Overseas Res, Rep.,* 1-19 (in Japanese).

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