Environ. Sci., Hokkaido	10 (1)	95~108	June 1987

Peatland and its Pollen Profiles in the Sanjiang Plain, Northeast China

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Abstract

Sixteen peat samples collected at three localities in and around the Sanjiang Plaing were investigated palynologically. Pollen profiles indicate vegetational successions and climatic changes during the Late Holocene. In the plain, *Quercus*, which is the main component of forests, declined and *Artemisia* increased during 2,300 years. In the hills and mountains around the plain, *Pinus* and *Picea* were dominant during 1,600 years. These three pollen profiles indicate a cool climate in the Late Holocene.

Key Words: Pollen profile, Peatland, The Sanjiang Plain in China, Vegetational succession, Climatic change.

Introduction

Peat is composed of an aggregate of plant remains, and moist climatic condition is necessary for peat accumulation. In the Japanese islands, the largest areas of peatland are found in Hokkaido. The authors have previously studied peatlands in Hokkaido, in palynological, geohistorical and climatological points of view.

The Sanjiang Plaing is located in the extreme northeast of China. The latitude is between northern Hokkaido and southern Sakhalin, and its climate resembles that of Hokkaido. The plain has the largest distribution of peatland in China.

In this preliminary report, the authors first detail the vegetation, Quaternary geology and topography of the plain. Next, the vegetational succession and climatic changes in the plain, which were investigated from pollen profiles collected in the plain by the authors. Finally, the climate of the Sanjiang Plain and Hokkaido is compared with each other.

1. Topography and Outline of the Quaternary Geology

1) *Topography*

The Sanjiang Plaing is located in the northeast of China, 45°1′N to 48°28′N and

130°13′ E to 135°5′E. It is an extensive plain between three big rivers, Heilong (Amur), Sonhua and Wusuli (Ussuri) (Figure 1). The plain has numerous monadnocks, while the other area is quite flat; in the southeast of the plain there is the Wanda Mountains. The area of the plain excluding the Wanda Mts. is estimated to be 51,300 km² (DMCIGAS, 1983).

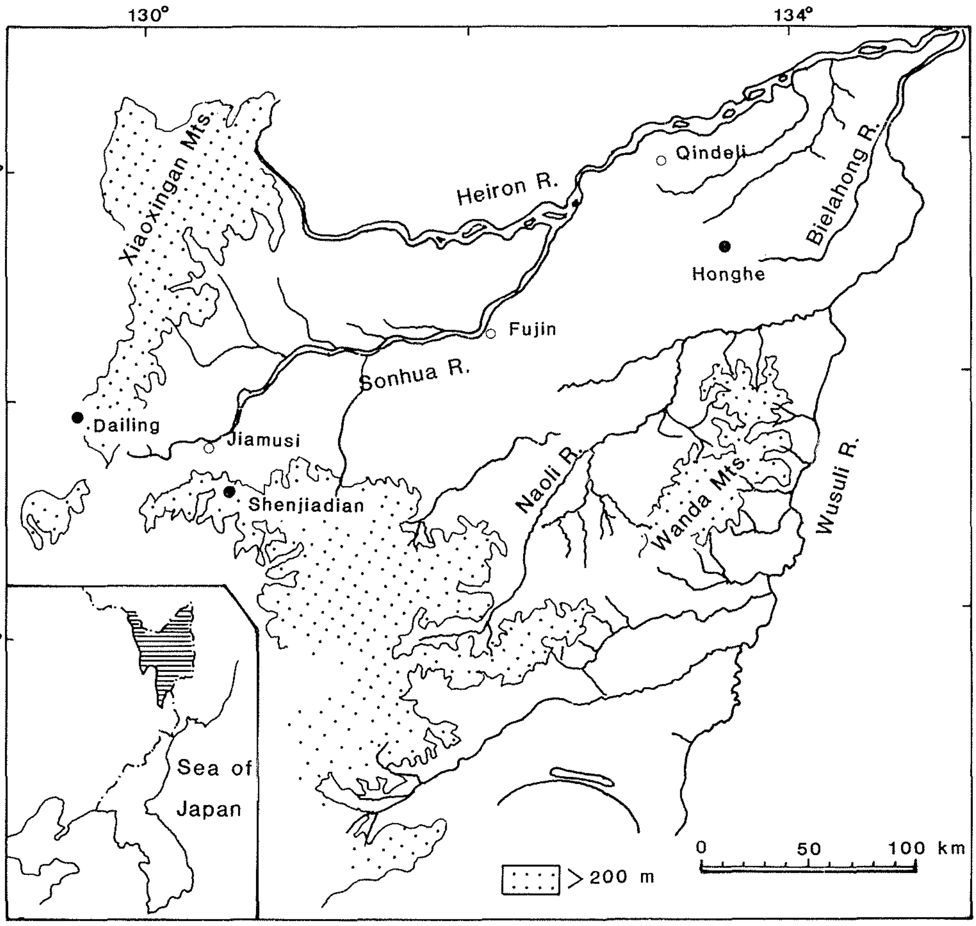

Figure 1. Map showing sampling sites (brack dot) and locations concerned.

The following is an outline of the topography (DMCIGAS, 1983).

i) Monadnocks

The plain is dotted with numerous small monadnocks which are distributed as isolated hills. In general, the top of the monadnocks are rounded. Little water erosion is seen on the slopes of the monadnocks. Their altitude is 80～150 m.

ii) Second Terrace

The Second Terraces are distributed mainly in the eastern part of the plain. They are gentle-rolling hills developed at altitudes of 55～100 m.

iii) First Terrace

The First Terraces are distributed in large areas of the plain, at altitude of 50 m～80 m. Their topography is rather flat, and is characterized by numerous swamp hollows.

iv) Swamp hollows

The Swamp hollows distribute on the First Terraces and on the higher flood plain along the big rivers, less than 55 m in elevation. Some of these are small dish-shaped or long and thin, and some have irregular shapes.

Table 1. The Quaternary stratigraphy of the Sanjiang Plain (After DMCIGAS)

Geological age				Formation	Sediments	Climate
QUATERNARY	Holocene	Late H.	Q_4^3	Qindeli F.	flood plain deposit sandy soil, sand, gravel	relatively cold relatively warm
		Middle H.	Q_4^2		swamp-river deposit silty sand, silt, clay	warm moist
		Early H.	Q_4^1		brack gyttja, peat	relatively warm relatively dry
	Pleistocene	Late P.	Q_3^3	Bielahong F.	clay	cold dry
			Q_3^2		silty clay, gyttja peat	cool relatively dry
			Q_3^1		sand, gravel & sand	relatively cold relatively warm
		Middle P.	Q_2^2	Xiang yang chuan F.	clay	relatively warm moist
			Q_2^1		alternation of sand & gravel·sand	cold dry
		Early P.	Q_1^2	Xiao qing he F	sand sand & gravel	relatively warm moist
			Q_1^1		gravel	cold dry

2) *Geology*

The stratigraphy of the Quaternary system in the plain is shown in Table 1 (DMCIGAS, 1983).

i) Lower Pleistocene (Xiaoginghe Formation)

The formation is distributed in a large area of the plain. It overlies the Tertiary system and is in turn overlaid by the Middle and Upper Pleistocene series. It is mainly composed of sand of grayish white to bluish gray, and pebbly sand and gravel. Its thickness is estimated to be 40～80 m.

ii) Middle Pleistocene (Xiangyangchuan Formation)

Most of the formation is overlaid by the Upper Pleistocene and Holocene series. It is mainly composed of grayish white to bluish gray sand, and pebbly sand and gravel. It contains thin layers of fine sand and silty clay, glacioaqueous sediments of the Middle Pleistocene age. Fossil bog wood, cross-bedding structures, and periglacial phenomena were also found. The thickness of the formation is estimated to be 30～50 m.

iii) Upper Pleistocene (Bielahong Formation)

The formation comprises the First Terrace. The stratigraphy of this formation is below in descending order as follows: yellowish brown clay, 3～17 m in thickness; grayish white～pale yellow fine sand with 2～15 m in thickness; bluish gray pebbly sand and gravel with 15～30 m in thickness. Fossil mammoth teeth have been found in the clay beds in the upper part of this formation.

iv) Holocene (Qindeli Formation)

This formation is distributed in the flood plains of rivers and in swamp hollows. In the area along the big rivers it is composed of sand and gravel, while in areas around rivers which originated from swamps it is composed of silty clay, silty sand and peat. In swamp hollows, it is mainly composed of peat.

As a result, unconsolidated clay, sand and gravel are accumulated in 100～200 m thick layers in the area without monadnocks. These Quternary systems are distributed in the same area as the Tertiary system, showing that the Sanjiang Plain is a typical fault basin formed by continuous crustal movement. The maximum depth of the submergence is believed to be nearly 300 m (Figure 2, Table 1).

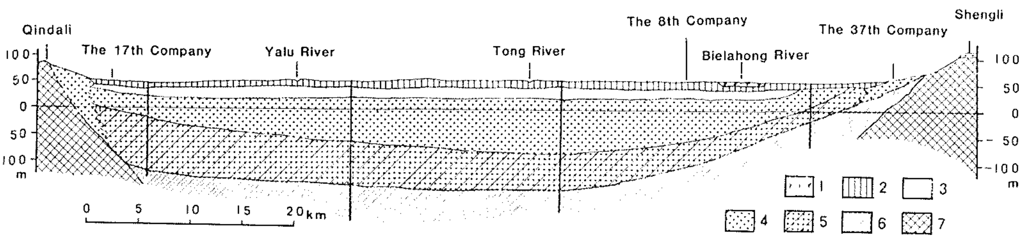

Figure 2. Geologic profile of the Sanjiang Plain (After data of Changchun Institute of Geography, Chinese Academy of Science)

2. Environmental Factors of Vegetation

The Sanjiang Plain is low and flat topographically, and the rivery flow is meandering. The annual precipitation is between 500 and 650 mm; it is not a large amount, but concentrated in summer. Precipitation varies considerably from year to year, and floods often occur in the plain (Takahashi, et al., 1986). The surface of the plain is covered by clay making drainage very slowly after flooding. Swamps and swampy meadows are formed in large areas for this reason.

The meteorological data resemble those of Hokkaido. The accumulated temperature of more than 10°C is between 2,500°C and 2,300°C, corresponding to that of east and north Hokkaido. The frost-free period, which indicates the climatic condition enabling plant growth, is between 120 and 145 days, with about 20 days shorter than in Hokkaido (Takahashi et al., 1986).

The present vegetation in the Sanjiang Plain has come into existence because of these topographic, geologic and meteorological factors.

3. Vegetation

Four vegetation types: forest, meadow, swamp, and aquatics were classified by Yi et al. (1982). More than 70% of the vegetation covering of the plain is swamps and swampy meadows.

1) *Forest*

Forests in the plain are of the *Quercus mongolica* Formation. They are distributed in belt-shapes or in island-shapes on hills, monadnocks and sand dunes in the plain (Figure 3). These are called "island forests". *Quercus mongolica* Formation is classified into two associations as follows. Companion species of each association are also shown.

Quercus mongolica Ass.: *Tilia amurensis*, *Tilia mandshurica*, *Lespedeza bicolor*, *Corylus heterophylla*, *Phellodendron amurensis*, *Paeonia lactiflora*, *Cacalia hastata*, *Convallaria keikei*, *Atractylis japonica* and *Odontites serotina*.

Populus davidiana-Betula platyphylla-Quercus mongolica Ass.: *Lespedeza bicolor*, *Corylus heterophylla*, *Filipendula intermedia*, *Anemone udensis*, *Sanguisorba*.

2) *Meadow*

Meadows are developed in the areas higher than their surroundings, areas with thick soil layers or well drained areas. These had generally been brought under cultivation by 1974 (Li et al., 1981, Figure 3). Meadows are classified into two types; typical meadows and swampy meadows. Both are further classified into two and three formations. Companion species of each formation are shown below.

i) Typical meadow

Deyeuxia angustifolia Formation: *Stachys baicalensis*, *Phragmites communis*, *Lythrum salicaria*, *Anemone dichotoma*, *Sanguisorba proviflora*, *Potentilla fragarioides*.

Betula fruticosa Formation: *Salix brachypoda*, *Sanguisorba proviflora*, *Patrinia intermedia*, *Pediculanis resupinata*, *Hemerocallis minor*.

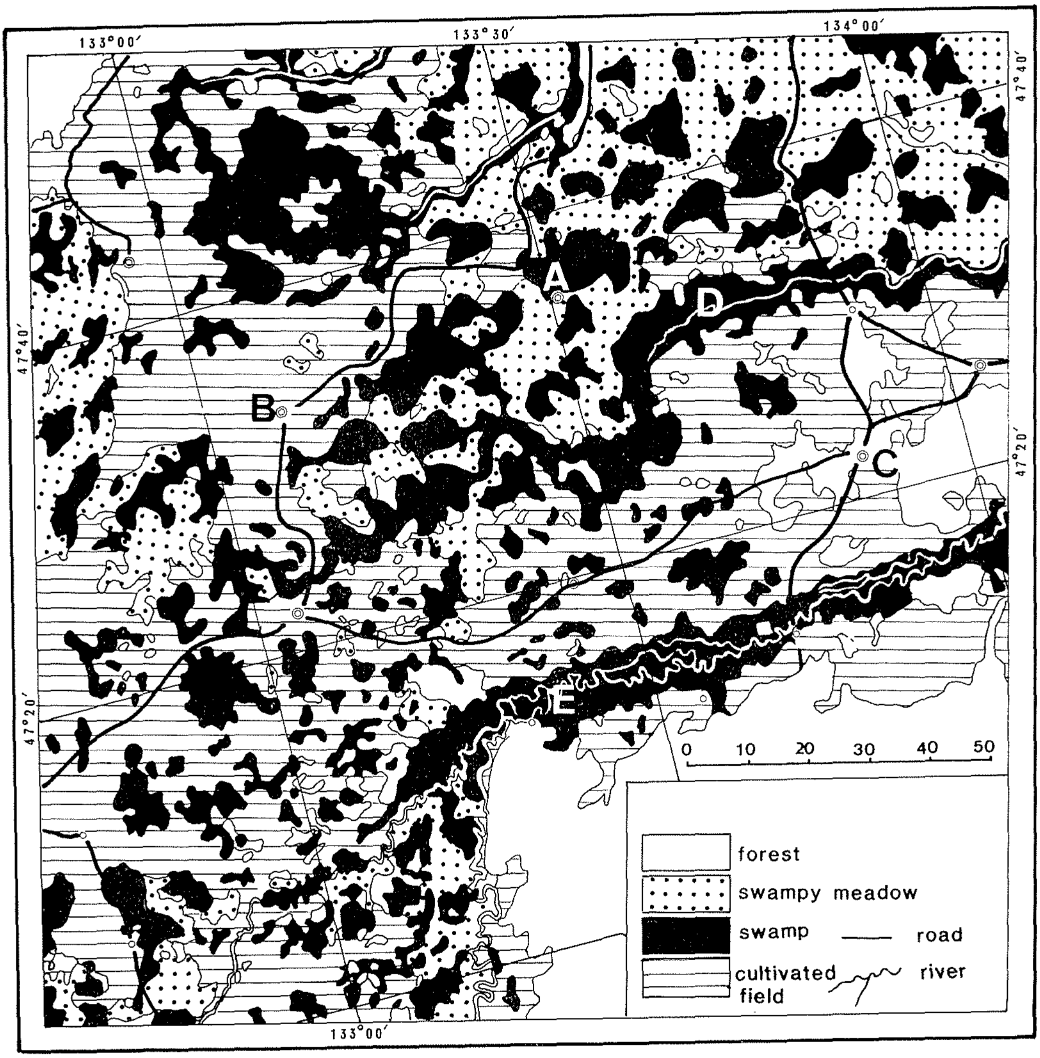

Figure 3. Map showing distribution area of forest, swampy meadow, swamp, cultivated field and locations described in the paper.
A. Honghe B. Qianjin C. Shengli
D. Bielahong River E. Qixing River

ii) Swamp meadow

Deyeuxia angustifolia—Carex spp. Formation : *Salix brachypoda, Carex schmidtii, Spiraea salicifolia, Anemone dichotoma, Phragmites communis, Stachys baicalensis, Lythrum salicaria, Drepanocladus aduncus, Carex appendiculata, Caltha palustris, Sanguisorba provifolia, Campylium chrysophyllum.*

Calamagrostis epigejos—Phragmites communis Formation : *Hemarthria japonica, Sanguisorba tenuifolia, Lysimachia davurica, Lathyrus quiquenervius, Lythrum salicaria.*

Alnus hirsuta Formation : *Betula fruticosa, Salix brachypoda, Spiraea salicifolia, Visia cracca, Galium bareale, Pteridium* sp., *Anemone dichotoma, Filipendula* sp., *Anemone udensis, Sanguisorba teunifolia.*

3) *Swamp*

Swamps are widely developed along the big rivers. Almost swamps are eutrophic. Among them, *Carex* swamp occupies 86% of the total swamp area in the plain. *Phragmites* swamp are dominant secondly. Swamp was classified into four formations.

i) *Carex appendiculata* Formation : *Salix brachypoda, Salix myrtilloides, Spiraea salicifolia, Deyeuxia angustifolia, Utricularis intermedia, Sparganium stenophyllum, Cicuta virosa* var. *tenuifolia, Juncus decipiens, Carex meyeriana, Sanguisorba proviflora, Caltha palustris, Lysimachia davurica, Sphagnum squarrosum.*

ii) *Carex lasiocarpa* Formation : *Comarum palustre, Menyanthes triforiata, Utricularis intermedia, Caltha palustris, Iris laevigata, Glyceria spiculosa, Phragmites communis, Naumburgia thysiflosa, Carex limosa, Eriophorum coreanum, Thelypteris palustris, Equisetum limosum, Sphagnum squarrosum, Sphagnum oligoperum.*

iii) *Carex pseudocuraica* Formation : *Comarum palustre, Menyanthes trifolia, Glyceria spiculosa, Deyeuxia langsdorffii, Glyceria spiculosa, Salvinia natans, Utricularis intermedia, Hippuris* sp.

iv) *Phragmites comunis* Formation : *Glyceria spiculosa, Caltha palustris, Salvinia natans, Deyeuxia angustifolia, Carex lasiolimosum, Stachys baicalensis, Iris laevigata, Salix brachypoda, Juncus decipiens, Sparganium stenophyllum, Utricularis intermedia, Cicuta virosa.*

4) *Aquatics*

Aquatics is classified into two types as follows :

i) Submerged rooted aquatics : *Myriophyllum ussuriens, Potamogeton tepperi.*

ii) Floating aquatics : *Nuphar pumilum, Nymphoides peltatam, Polygonum amphibium.*

4. Peatland

The total area of peatland in China is estimated at 4,159,000 ha, 0.45% of the total land area. Surface peatlands are 83.6% for the total, and 58% of this area is in northeast China, especially in the Sanjiang Plain. Three percent of the plain is occupied by peatland (Chai, 1981).

Peat is mainly accumulated in swamps. Swamp soils in the plain are classified into six types (Zhang, 1981) :

1. Swampy meadow soil
2. Alkaline swampy meadow soil
3. Humiceous swamp soil
4. Peaty swamp soil

5. Muddy swamp soil
6. Peat soil

Among these, "peaty swamp soil" and "peat soil" have peat layers. The "peaty swamp soil" is mainly accumulated at the base of mountains, and the surface of this area is permanently covered with water. *Carex lasiocarpa*, *Carex limosa* and *Carex meyeriana* are common on the "peaty swamp soil". The thickness of peat is 30～50 cm.

The "peat soil" accumulated in the old river courses, lakes, hollows on terraces and flood plains of rivers have an average peat thickness of 1～2 m, the maximum thickness reaches 5 m. In general, peat is thicker in the south than in the north of the plain. Vegetation in the area is mainly composed of *Carex meyeriana*, *Carex pseudocuraica* and *Menyanthes trifoliata*.

Thus, peatlands in the Sanjiang Plain are developed in eutrophic conditions which are indicated by the dominance of Carex. Peatland developed in mountain areas such as the Xiaoxingan Mts. (Figure 1) and the Changbai Mts. are formed in oligotrophic conditions, with the vegetation mainly composed of *Larix* and *Sphagnum* (Lang et al., 1983).

5. Pollen Assemblages of Peat

Pollen samples were collected from three locations: Honghe, Shenjiadian and Dailing (Figure 1). The results of pollen analysis are described below.

1) *Honghe*

The sampling point is a swamp about 4 km southeast from the center of the Honghe Farm. The stratigraphy of the Honghe Section is:

0～10 cm — grass roots
10～15 cm — white gley soil
15～55 cm — brown peat
55～75 cm — black well decomposed peat
75～95 cm — compact black clay containing organic matters

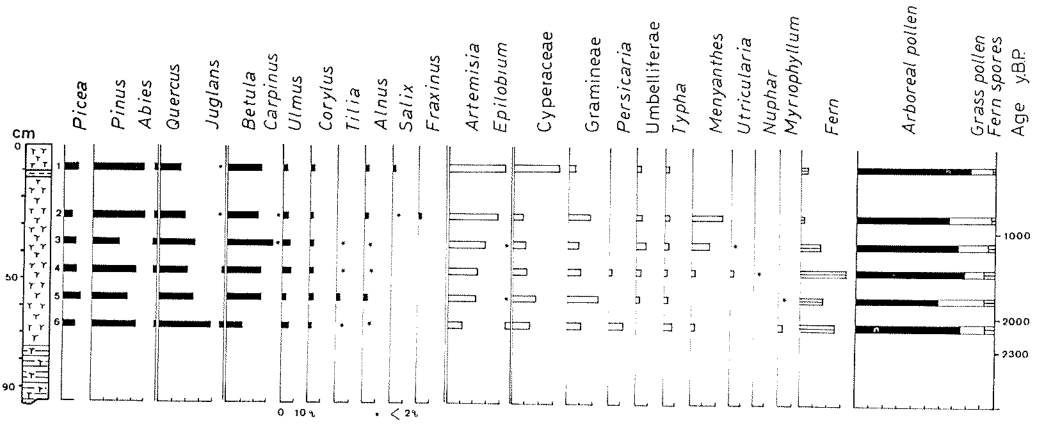

Figure 4. Pollen diagram from Honghe Section.

Table 2. Rare pollen percentages of Honghe Section

Sample numbers	*Larix*	*Ostrya*	*Hydrangea*	*Sanguisorba*	Compositae	Chenopodiaceae	*Thalictum*	Valerianaceae	Rosaceae	Tricolportae type	Tricolpate type
1	0.3	0.3		1.5	1.5	1.5		1.5	1.2	3.0	
2						2.9	1.0			2.9	
3	0.5			2.5	1.2	2.5					6.2
4				1.3	4.0	1.3	1.3				
5			1.6	5.6	2.3	1.1				4.5	
6					6.0	1.5	1.5				

Six samples from the profile were analyzed for pollen and spores, as shown in Figure 4 and Table 2. Arboreal pollen percentages (AP) were calculated for the AP total. Percentages of grass pollen and fern spores were calculated for the total amount of grass pollen and spores. High frequencies of *Quercus*, *Pinus*, and *Betula* were recognized in all samples. However, *Quercus* falls upwards. Other trees such as *Picea*, *Abies*, *Ulmus*, *Corylus*, and *Alnus* were contained in relatively high percentages. Besides *Juglans*, *Carpinus*, *Tilia*, *Salix*, *Fraxinus*, *Ostrya*, and *Hydrangea* occurred in low. *Tilia* and *Corylus* are the present components of the "island forest" of the Sanjiang Plain. Compared with pollen assemblages of peat in Hokkaido, the frequency of *Alnus* are extremely low.

On the other hand, the most dominant grass taxum was *Artemisia*. *Artemisia* frequency increased towards to surface. *Carex*, which is main component of swamps, was below 30%. Cyperaceae increased abruptly at the surface. Aquatics such as *Typha*, *Menyanthes*, *Utricularia*, *Nuphar*, and *Myriophyllum* were found in high frequencies. Fern decreases upwards. Only little of other taxa such as *Sanguisorba*, Compositae, Chenopodiaceae, *Thalictrum*, Valerianaceae and Rosaceae was detected.

2) *Shenjiadian*

Shenjiadian peatland is located in the northernmost part of the Changbai Mts., south of Jiamusi City (Figure 1). Peatlands are in the shape of an oval among the hills, 162 m above sea level. The maximum thickness of peat is 2 m. Compact black 30 cm thick peat containing seed of *Menyanthes* was collected.

Pinus was dominant within 80% and *Picea* in the lowest horizon was 60%. The frequency of conifer pollen for the total AP was higher than at Honghe. *Quercus* and *Betula* were below 14%. This is lower than Honghe. Only little of *Juglans*, *Ulmus*, *Carpinus*, *Tilia*, *Populus*, *Corylus*, *Celtis* and *Styrax* was detected (Figure 5, Table 3).

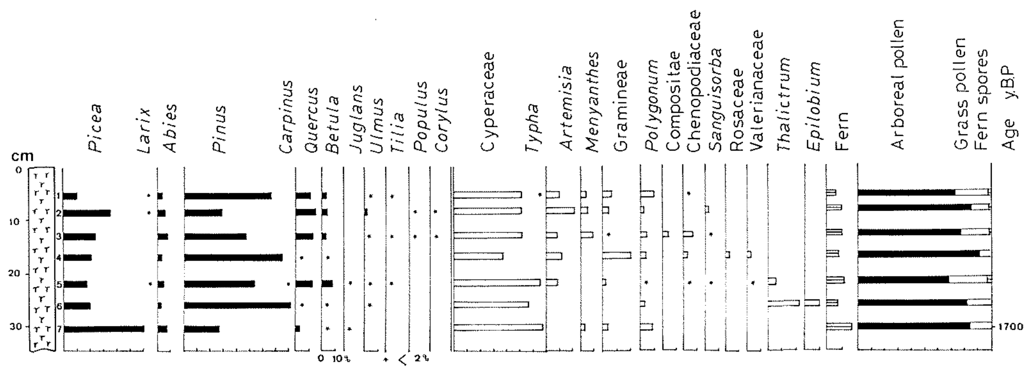

Figure 5. Pollen diagram from Shenjiandian Section.

Table 3. Rare pollen percentages of Shenjiandian Section

Sample numbers	*Celtis*	Leguminosae	Cruciferae	Caryophyllaceae	Liliaceae	Tricolporate type	*Sphagnum*
1		1.4	1.4			6.9	
2	0.4		2.4	2.4			
3							
4						3.9	
5				1.0	1.0		1.0
6				2.1			
7							

Among the undergrowth, Cyperaceae was most common, up to 70%. Other taxa, such as *Artemisia*, Gramineae, *Menyanthes*, Polypodiaceae, Compositae, Chenopodiaceae, *Sanguisorba*, Rosaceae, *Thalictrum*, and *Epilobium* were relatively common.

3) *Dailing*

Fifty-five centimeters long peat samples were collected from a high moor in the southernmost Xiaoxingan Mts., 300 m above sea level (Figure 1). Vegetation around the moor was the mixed forest mainly composed of *Pinus koraiensis*, *Picea koraiensis*, *Abies nephrolepis*, *Quercus mongolica*, *Betula*, *Acer*, *Tilia* and *Ulmus*. The moor surface was covered mainly with *Sphagnum*, and *Larix gmelini* and *Alnus sibilica* were scattered in the moor. As a result, the frequency of *Pinus* pollen reached 80% and *Picea* was within 20% (Figure 6, Table 4). Though *Larix* grew in the moor, *Larix* pollen was less than 2%. The broad-leaved tree of high frequency was *Betula*. *Quercus* was below 10%. Other broad-leaved trees such as *Ulmus*, *Corylus*, *Alnus*, *Tilia*, *Acer*, *Hydrangea*, *Salix*, *Juglans*,

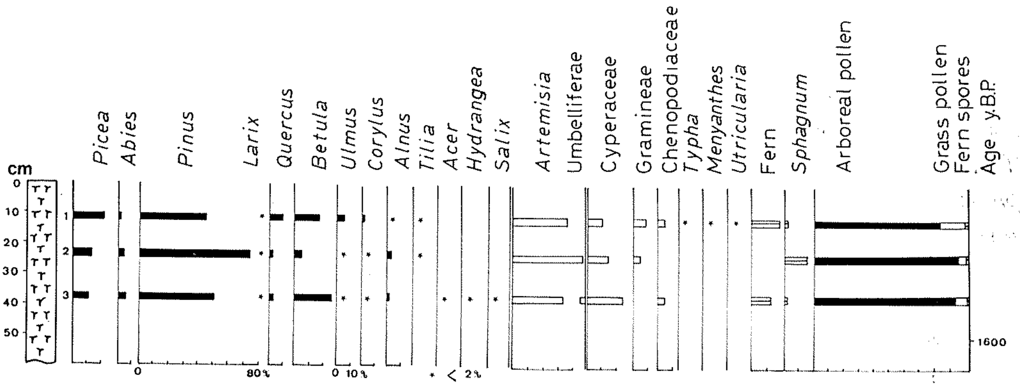

Figure 6. Pollen diagram from Dailing Section

Table 4. Rare pollen percentages of Dailing Section

Sample numbers	*Juglans*	Araliaceae	Ericaceae	*Polygonum*	*Iris*	*Sanguisorba*	*Thalictrum*	Ranunculaceae	Tricolporate type	Triporate type
1	0.4			3.0	1.0	2.0	1.0	3.0	3.0	
2			0.2						17.0	
3	0.7	0.4			1.5	1.5	3.0	4.4	3.0	1.5

Araliaceae and Ericaceae were found in low frequencies.

Of grasses, *Artemisia* occupied about 40%. Cyperaceae declines upwards. *Sphagnum* was within 15%. In the uppermost sample, aquatics such as *Typha*, *Menyanthes* and *Utricuria* were detected within 2%.

6. Vegetational Succession and Climatic Change

1) *Ages of peat*

The accumulation rate of the peat varies due to climatic conditions. During the Middle Holocene it was 0.66 mm/yr in a warm-moist climatic condition. In the Early and Late Holocene, it declined to 0.3~0.4 mm/yr. It was 0.33 mm/yr at Qindeli in the Sanjiang Plain, and 0.24 to 0.3 mm/yr in the Xiaoxingan Mts. (Ma, 1982). With these accumulation rates, 75 cm thick Honghe peat began to accumulate about 2,300 years ago. The accumulation rate of Shenjiadian peat has been calculated to be 0.18 mm/yr (Zhou et al., 1984), giving a peat age 30 cm below the surface of about 1,700 years B.P.. The 50 cm thick peat in Dailing has accumulated during the last 1,600 years.

2) *Vegetational succession*

Vegetational successions reconstructed from pollen profiles are described below.

In the Sanjiang Plain, *Quercus mongolica,* main component of the 'island forest" continued to decline during last 2,300 years. *Juglans* and *Tilia amurensis* and/or *Tilia mandshurica* also declined. However, *Betula platyphylla, Corylus heterophylla, Ulmus* and *Alnus* were constantly distributed. On the other hand, *Artemisia* increased and fern decreased.

In the hill area, mixed forest of *Pinus koraiensis, Picea, Abies* and broad-leaved trees such as *Quercus mongolica, Betula, Ulmus* were distributed during the last 1,700 years.

On the other hand, in the low mountains, mixed forest mainly composed of *Pinus koraiensis, Picea koraiensis* and *Betula* were developed since 1,600 years B.P..

3) *Holocene climatic change in China*

Holocene climatic change in northeast China has been clarified by pollen analysis (Zhou et al., 1984 ; Qiu et al., 1981 ; Yin, 1984).

Between 10,000 and 7,500 years B.P., *Betula, Pinus* and *Alnus* were dominant. Climate during the Early Holocene fluctuated from relatively warm-mosit to relatively cold-dry, and back to warm-moist. From 7,500 to 2,500 years B.P., broad-leaved trees increased due to the warm-moist climate. However, during the last 2,500 years, *Pinus* and *Betula* increased again. Climate in the Late Holocene changed to cool-dry.

All peat samples in this paper belong to the Late Holocene age. However, the pollen profile of Honghe shows more detailed climatic changes. *Quercus mongolica,* the main component of the "island forest" continued to decline during the last 2,300 years, as did *Juglans* and *Tilia amurensis* and/or *Tilia mandshurica,* while *Artemisia* increased. This shows that the climate in the plain has become increasingly cool-dry during the last 2,300 years.

4) *Correlation with climatic change in Hokkaido*

The geographic position of the Sanjiang Plain is between northern Hokkaido and southern Sakhalin, and the meteorological conditions in Hokkaido resemble those of China.

Holocene climatic change in Hokkaido is detailed below (Igarashi, 1986 ; Igarashi and Takahashi, 1985 ; Nakamura, 1986 ; Takahashi and Igarashi, 1986) :

From 10,000 (9,700) to 8,000 years B. P., *Betula, Picea* and *Juglans* increased steeply, but the climate was still cooler than at present. Between 8,000 and 5,000 years B. P., temperate broad-leaved trees such as *Quercus, Betula, Ulmus, Juglans* and *Alnus* were dominant in a warm-moist climate. From 5,000 to 4,000 years B. P., there was a relatively cold term, suggested by increasing *Picea* and *Tsuga.* From 4,000 to 2,000 years B. P., the climate became warm again. Since 2,000 years B. P., increase of *Picea* in the mountain areas shows a cool-moist climate. Cool climate in the Late Holocene was the same in northeast China and in Hokkaido. But aridity in both area was different each other.

Conclusion

Pollen profile from Honghe, northeast in the Sanjiang Plain shows changes of vegetation and climate in the plain during the last 2,300 years. *Quercus mongolica*, the main component of the "island forest" continued to decline. *Juglans* and *Tilia* shows the same decreasing trend, while there was no change in *Betula*, *Ulmus*, *Corylus* and *Alnus*. *Artemisia* continued to increase but, ferns declined towards the upper layers. These features of pollen profile show that the climate in the plain became cool-dry during the last 2,300 years.

The pollen profile of Shenjiandian, at the extreme west of the plain, was characterized by a dominance of *Pinus* and *Picea*. The frequency of *Quercus* and *Betula* was smaller than at Honghe.

The pollen profile of Dailing, southernmost in the Xiaoxingan Mts., is characterized by a dominance of *Pinus*, *Betula* and *Picea*.

These three pollen profiles show cool climate in the Late Holocene age (Q_4^3 in stratigraphy of China). The same cool climate in the Late Holocene is also shown in Hokkaido by increase of *Picea* pollen in mountain areas.

Acknowledgements

This study was carried out as the research project of the Hokkaido Peatland Society, and was supported in part by the Northern Region Center in Hokkaido and Changchun Institute of Geography, Chinese Academy of Science. The authors wish to thank Prof. Zheming Liu and Prof. Xingtu Liu, Changchen Institute of Geography and Prof. Yasuharu Umeda of Faculty of Agriculture, Hokkaido University for their useful suggestion. Thanks are also due to Mr. Huanchen Zhao and Mr. Chonghao Li of Changchun Institute of Geography for their advice and cooperations.

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(Received 28 February 1987)