Late Holocene Vegetation in Numamukai, Sendai City, Northeast Japan

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Akihiro YOSHIDA[*1] **and Sadako TAKEUTI**[*2]

Abstract Pollen analysis and ^{14}C dating were made on core samples obtained from Numamukai in the northeastern part of Miyagino coastal plain, Miyagi Prefecture. The core covers from about 1,300 years ago to present and can be subdivided into three local pollen zones, NM-1, NM-2, and NM-3 in ascending order.

The vegetation changes in and around the area since about 1,300 years ago are as follows.

Period of NM-1 (ca. 1,300~1,100 yrs BP): *Quercus* forest

Period of NM-2 (ca. 1,100~1,000 yrs BP): In addition to *Quercus* forest, *Pinus densiflora* secondary forest and *Cryptomeria japonica* plantation

Period of NM-3 (ca. 1,000 yrs BP~present): *Pinus densiflora* secondary forest and *Cryptomeria japonica* plantation

Rice paddy field cultivation was begun in the Numamukai area in Period of NM-2, and the vegetation was conspicuously changed by human activities as mentioned above.

In and around the Miyagino coastal plain at about 1,200 years ago, the forest composed chiefly of *Fagus* covered on the lower part of the mountains and the upper part of the hilly lands, and that of *Quercus* was distributed in the main part of the plain. The lower part of the hilly lands and the margin of the plain was transitional zone.

Key words: Late Holocene, Pollen analysis, ^{14}C age, Vegetation changes, Numamukai, Miyagino coastal plain, Northeast Japan

1. Introduction

The vegetation changes in the Miyagino coastal plain and the hilly lands, Miyagi Prefecture, in the middle and late Holocene were summarized by Morita and Hibino (1994) and Hibino and Takeuti (1998) based on palynological studies. Whereas Takeuti *et al.* (2005) clarified the vegetation changes in the coastal plain since early

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Holocene.

The destruction of natural vegetation by ancient human activities in and around the Miyagino coastal plain began in the middle Holocene. The human activities became aggressive after about 1,000 years ago with consequent large progress of vegetation changes (Yasuda, 1973 ; Takeuti, 1974 ; Yoshida and Saijo, 2005).

This paper presents the results of the palynological analysis and ^{14}C dating of the sediment samples from the borehole at Numamukai in the northeastern part of the Miyagino coastal plain, and besides, it discusses the relationship between human activities and vegetation changes in this area since about 1,000 years ago. An attempt is also made to elucidate the vegetation and topographic environment in and around the plain at about 1,100 years ago based on the palynological data obtained from many sites.

2. Study area

2.1 Geographic setting

Miyagino coastal plain, Miyagi Prefecture, situated in the southern part of Northeast Japan, is the alluvial plain about 40 km long from north to south and 10 km wide from east to west along the Pacific coast (Fig. 1). The plain is crescent-shaped with its convex side directing westward and is surrounded by the hilly area, 100 to 200 m in altitude. The Nanakita, Natori, and Abukuma Rivers flow eastward on the plain and run into the Pacific Ocean. According to Matsumoto (1985), "There are natural levees and abandoned channels along and near river channels. Several beach ridge ranges run along the coastline, and they are in three rows above the plain surface. Beach ridge range I (BR-I) is the innermost one ……" and "Back marsh extended widely behind BR-I. A wood sample collected from this back marsh deposit was measured 4,315±150 ^{14}C yrs BP (TH-180). Therefore it is assumed that BR-I had been formed up to about 4,300 yrs BP"

The Numamukai area is on both BR-I and inner back marsh composed of sand and of peat respectively on the northern side of the Nanakita River (Fig. 1). Recently, many archaeological sites on and after Kofun age were found in this area (Sendai City Board of Education, 2000).

2.2 Vegetation

The Miyagino coastal plain is situated in the transitional zone between the cool temperate and warm temperate zones from the climatical viewpoint.

The original vegetation of the plain is the climax forests composed mainly of *Abies firma* and *Fagus japonica* (Miyawaki, 1987). Most of the forests are now the secondary ones which have been degenerated by incessant human impacts for long

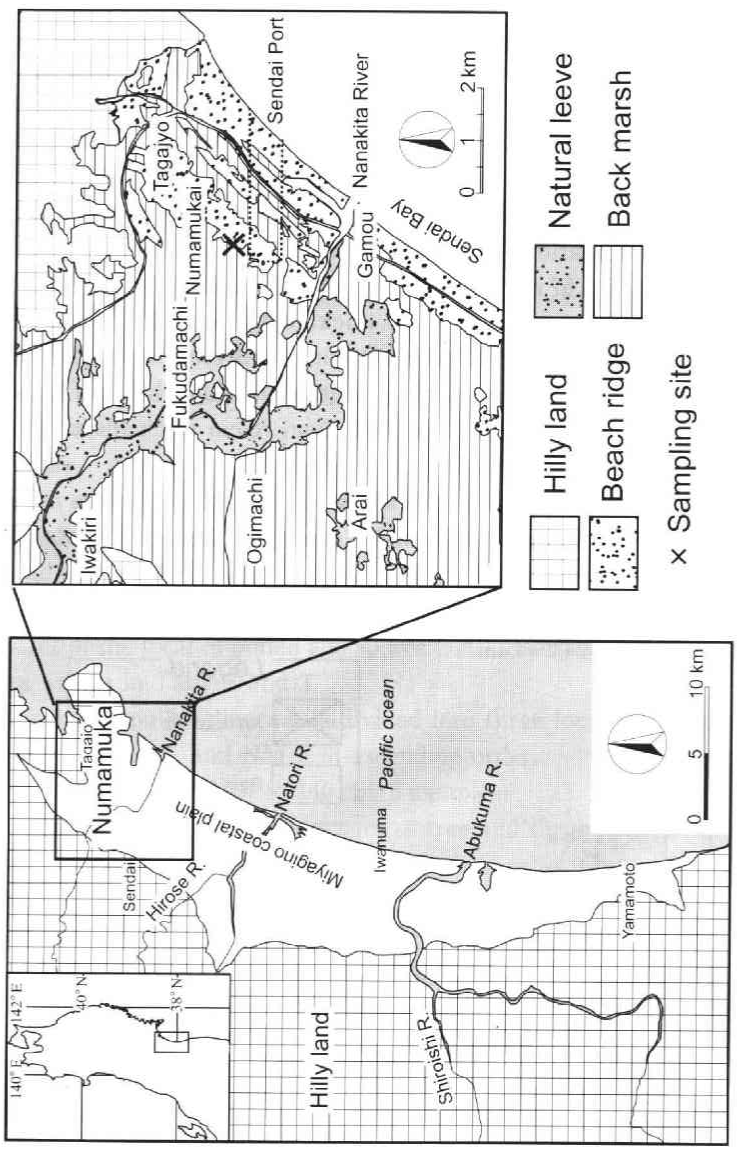


Fig. 1 Index map of the study area and sampling site
Geomorphological map is after Matsumoto (1985) with some revision.

time. Main part of the plain has been mostly cultivated to produce rice and other crops. Therefore, the forests of climax types are very rare and only *Alnus japonica* forests are partly distributed around the rice paddy fields and marshes.

3. Core sample and radiocarbon age

Sedimentary core obtained for the investigation, with Geo-slicer, is 2.5 meters in length. Sampling site is located at an altitude of 1.4 m a.s.l. in the marginal part of the inner back marsh (38°16′37″N, 141° 60′26″E) (Fig. 1). Sediments of the core comprise in ascending order, 16 cm thick (depth of 2.5-2.34 m) granule-sized gravels, 61 cm thick (depth of 2.34-1.73 m) alternation of laminated medium to fine grained sand and peat, 15 cm thick (depth of 1.73-1.57 m) fine grained sand, 12 cm thick (depth of 1.57-1.45 m peat including many plant remains, 10 cm thick (depth of 1.45-1.35 m) laminated medium to fine grained sand intercalated with thin peat layers, 65 cm thick (depth of 1.35-0.7 m) peat including abundant wood fragments and a thin white tuff bed assigned to To-a (Sendai City Board of Education, 2000), and 70 cm thick (depth of 0.7-0 m) artificial fills (Fig. 2).

Wood fragment from the depth of 1.7-1.73 m of sediment core was subjected to radiocarbon dating by Prof. Omoto, Nihon University. The radiocarbon date was

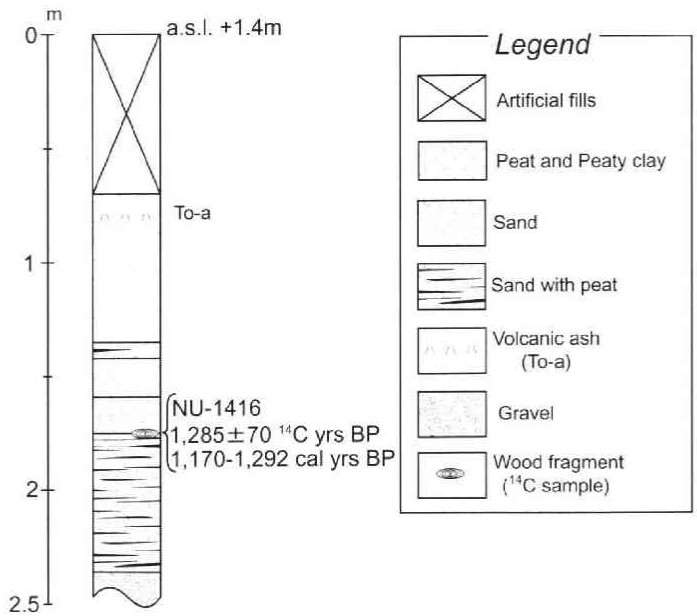


Fig. 2 Columnar section of core from Numamukai

Table 1 Result of radiocarbon dating

Depth (m)	Material	Code No.	$\delta^{13}C$ (‰)	^{14}C age (yrs BP)	Calibration age (1σ)*2 (cal yrs BP)
1.7-1.73	Wood fragment	NU-1416*1	−30.2	1,285±70	1,170-1,292

*1 Original sample was mixed with background sample
*2 Radiocarbon calibration program CALIB REV5.0.1 (Stuiver *et al.*, 1998)

calibrated using CALIB5.0 (Stuiver *et al.*, 1998). The results of dating are shown in Table 1.

4. Pollen analysis

Eleven samples for pollen analysis were taken from the core at 10 cm to 30 cm intervals. These sediment samples were treated with 10% KOH and 34% HF solutions and subsequently acetolysed, and finally pollen materials were embedded in glycerin jelly. At least 300 tree and shrub pollen grains were counted in each sample. Herbaceous pollen and fern spore grains were counted at the same time.

The pollen results are given as a percentage pollen diagram (Fig. 3). Frequencies of tree and shrub pollen taxa are expressed as percentages of a tree and shrub pollen sum, and those of pollen and spore types from herbaceous plants are expressed as percentages of the total of pollen and spores. All identified pollen taxa and fern spore types are shown in Table 2 and 3.

The resulted pollen diagram is divided into three local pollen assemblage zones, namely NM-1, NM-2, and NM-3 in ascending order.

Zone NM-1 (Depth: 250 to 140 cm, 5 samples)

This zone marks a high percentages of tree and shrub pollen. On an average the temperate deciduous broad-leaved trees such as *Quercus*, *Carpinus*, and *Fagus* are well represented. *Salix* pollen value is fairly high in the beginning of this zone, and it decreases upward. The percentage for the herbaceous pollen is low.

Zone NM-2 (Depth: 140 to 85 cm, 5 samples)

This zone is characterized by rather high herbaceous values which are mainly caused by the abundance of Gramineae and Cyperaceae. Among trees and shrubs, *Quercus*, *Fagus*, and *Carpinus* are still dominant, and they are accompanied by *Pinus* and *Cryptomeria*. Percentage for *Salix* is very low.

Zone NM-3 (Depth: 85 to 70 cm, 2 samples)

In this zone, percentages for *Cryptomeria* and *Pinus* are higher than those in zone NM-2, while those for the broad-leaved trees mentioned above are lower. Herbaceous pollen which consist mainly of Gramineae and Cyperaceae reach a higher value.

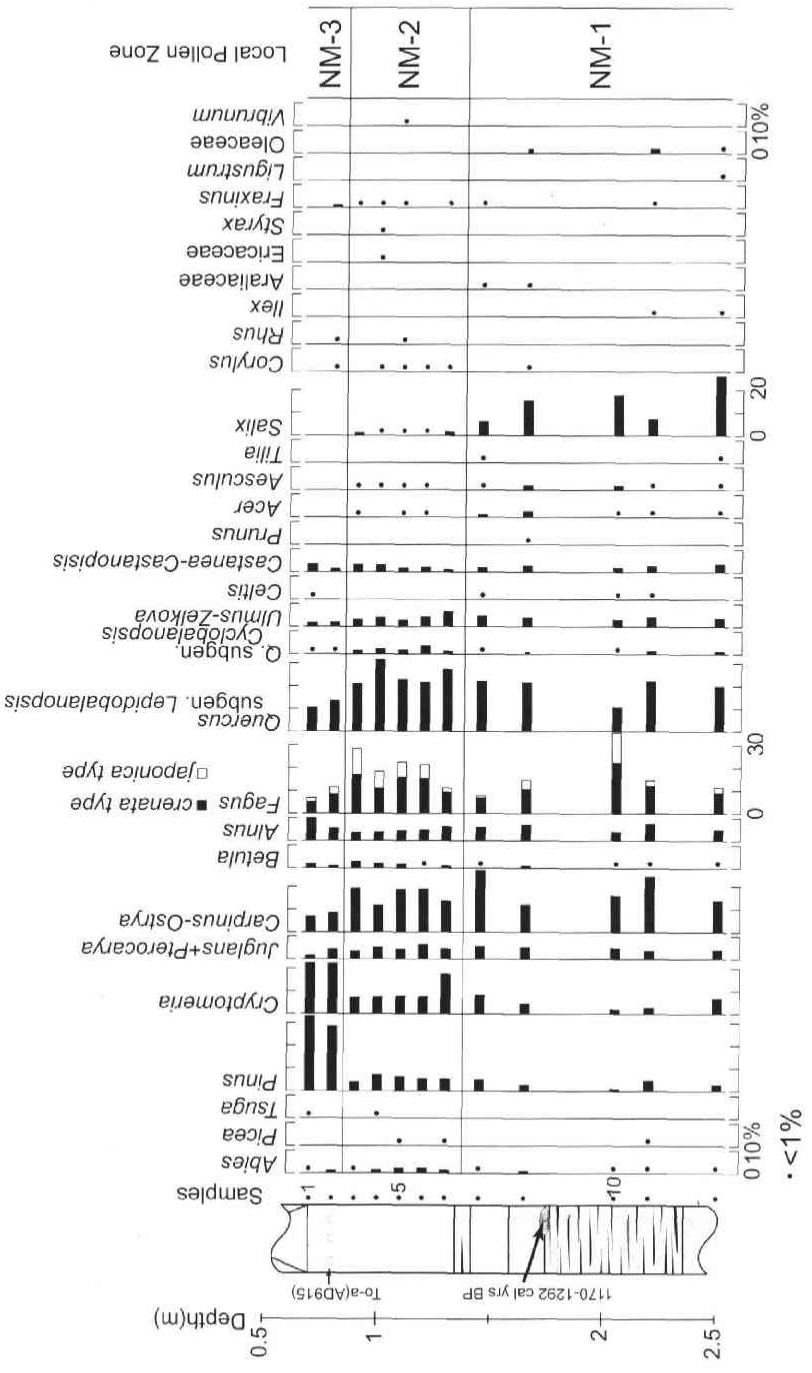


Fig. 3-1 Pollen percentage diagram of core from Numamukai
Symbols are the same as those in Fig. 2.

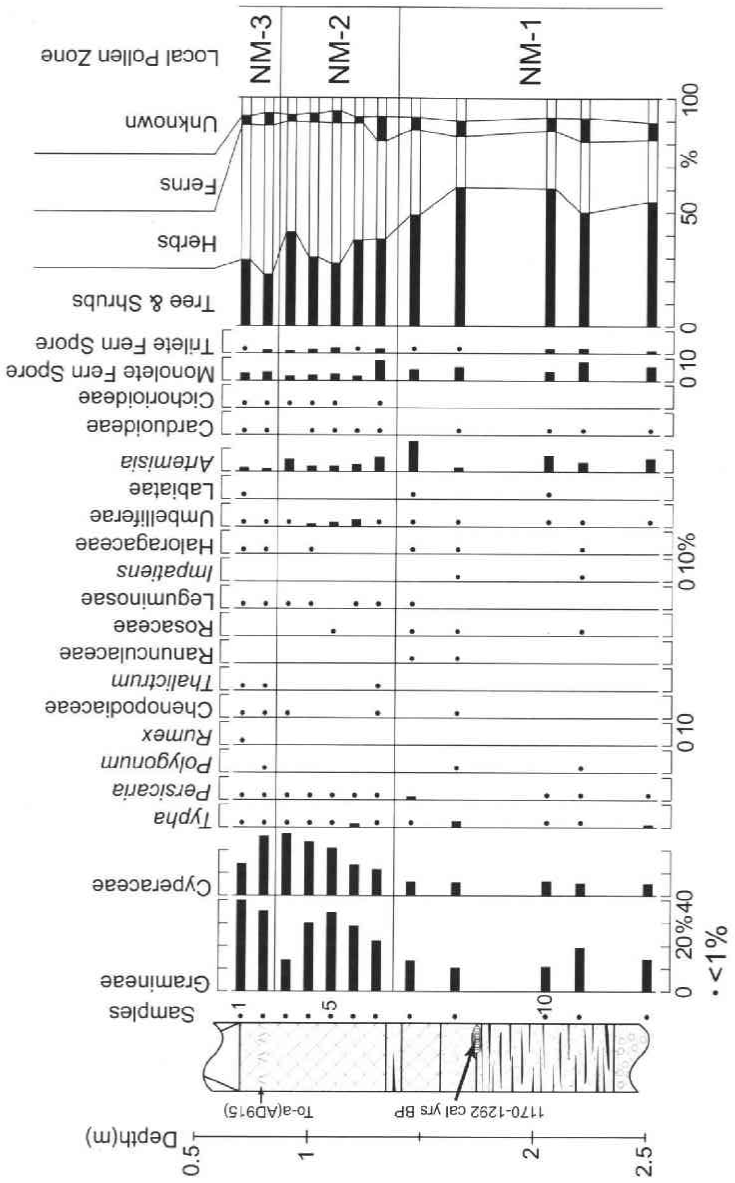


Fig. 3-2 Continue

Table 2-1 Pollen counts of core from Numamukai

Sample No.	Depth(cm)	*Abies*	*Picea*	*Tsuga*	*Pinus*	*Cryptomeria*	*Juglans+Pterocarya*	*Carpinus-Ostrya*	*Betula*	*Alnus*	*Fagus crenata*	*Fagus japonica*	*Fagus*	*Quercus* subgen. *Lepidobalanopsis*	*Quercus* subgen. *Cyclobalanopsis*	*Quercus*	*Ulmus-Zelkova*	*Celtis*	*Castanea-Castanopsis*	*Prunus*	*Acer*	*Aesculus*	*Tilia*	*Salix*	*Corylus*	*Rhus*	*Ilex*	Araliaceae	Ericaceae	*Styrax*	*Fraxinus*	*Ligustrum*	Oleaceae	*Viburnum*	Local Pollen Zone
1	215	3		1	113	76	6	23	6	34	17	6	23	36	2	38	6	1	12																
2	210	3			87	67	13	25	3	16	25	10	35	41	1	42	6		4					1	1					3					NM-3
3	205	1			12	22	11	59	9	11	53	35	88	65	5	70	10		10		2	1		3						2				
4	200	4		1	21	22	16	35	6	11	33	22	55	95	7	102	12		9			1		2	1			1	1	1				
5	195	6	1		19	23	13	56	5	13	48	20	68	69	5	74	9		5		1	1		2	2	1				1			1	NM-2
6	190	6			16	22	19	56	2	14	46	18	64	65	11	76	13		6		1	1		2	1									
7	185	4	2		16	53	14	41	3	19	28	6	34	83	4	87	20		3					5	1					2				
8	178	1			16	26	18	86	2	19	22	3	25	70	1	71	15	3	6		4	2	1	19			1			2				
9	168	3			8	14	16	37	3	22	33	12	45	67	3	70	12		8	1	8	6		47	2		2					6		
10	148	2	1		14	8	11	74	2	23	37	7	44	68	4	72	13	1	8		2	1		22		1				1		6		NM-1
12	140	1			3	6	15	50	1	12	70	41	111	33	2	35	10	1	6		2	6		55										
11	125	1			8	20	12	41	1	14	27	8	35	60	3	63	11		10		2	2	1	79		1					2	1		

Table 3-1 Pollen percentages of core from Numamukai

Sample No.	Depth(cm)	*Abies*	*Picea*	*Tsuga*	*Pinus*	*Cryptomeria*	*Juglans+Pterocarya*	*Carpinus-Ostrya*	*Betula*	*Alnus*	*Fagus crenata*	*Fagus japonica*	*Fagus*	*Quercus* subgen. *Lepidobalanopsis*	*Q.* subgen. *Cyclobalanopsis*	*Quercus*	*Ulmus-Zelkova*	*Celtis*	*Castanea-Castanopsis*	*Prunus*	*Acer*	*Aesculus*	*Tilia*	*Salix*	*Corylus*	*Rhus*	*Ilex*	Araliaceae	Ericaceae	*Styrax*	*Fraxinus*	*Ligustrum*	Oleaceae	*Viburnum*	Local Pollen Zone
1	215	0.9		0.3	33.0	22.2	1.8	6.7	1.8	9.9	5.0	1.8	6.7	10.5	0.6	11.1	1.8	0.3	3.5																
2	210	1.0			28.4	21.9	4.2	8.2	1.0	5.2	8.2	3.3	11.4	13.4	0.3	13.7	2.0		1.3					0.3	0.3					1.0					NM-3
3	205	0.3			3.9	7.1	3.5	19.0	2.9	3.5	17.0	11.3	28.3	20.9	1.6	22.5	3.2		3.2		0.6	0.3		1.9						0.6				
4	200	1.3		0.3	7.0	7.3	5.3	11.6	2.0	3.7	11.0	7.3	18.3	31.6	2.3	33.9	4.0		3.0			0.3		0.7	0.3			0.3	0.3	0.3					
5	195	2.0	0.3		6.3	7.6	4.3	18.6	1.7	4.3	15.9	6.6	23.6	22.9	1.7	24.6	3.0		1.7		0.3	0.3		0.7	0.7	0.3				0.3			0.3		NM-2
6	190	2.0			5.4	7.4	6.4	18.7	0.7	4.7	15.4	6.0	21.4	21.7	3.7	25.4	4.3		2.0		0.3	0.3		0.7	0.3										
7	185	1.3	0.7		5.3	17.4	4.6	13.5	1.0	6.3	9.2	2.0	11.2	27.3	1.3	28.6	6.6		1.0					1.5	0.3					0.7				
8	177.5	0.3			5.0	8.2	5.7	27.1	0.6	6.0	6.9	0.9	7.9	22.1	0.3	22.4	4.7	0.9	1.9		1.3	0.6		6.0			0.3			0.6				
9	167.5	1.0			2.6	4.5	5.2	11.9	1.0	7.1	10.6	3.9	14.5	21.6	1.0	22.6	3.9		2.6	0.3	2.6	1.9		15.2	0.6		0.6					1.9		
12	147.5	0.3			1.0	1.9	4.8	15.9	0.3	3.8	22.3	13.1	35.4	10.5	0.6	11.1	3.2	0.3	1.9		0.6	1.9		17.5										NM-1
10	140	0.7	0.3		4.6	2.6	3.6	24.2	0.7	7.5	12.1	2.3	14.4	22.2	1.3	23.5	4.2	0.3	2.6		0.7	0.3		7.2		0.3				0.3		2.0		
11	125	0.3			2.6	6.6	3.9	13.5	0.3	4.6	8.9	11.5		19.7	1.0	20.7	3.6		3.3		0.7	0.7	0.3	26.9		0.3					0.7	0.3		

Numbers of tree and shrub pollen taxa are expressed as percentages of a tree and shrub pollen sum, and those of pollen and spore types from herbaceous plants are expressed as percentages of the total of pollen and spores.

5. Discussion

5.1 Vegetation history in the Numamukai area during past 1,300 years

Vegetation succession in the Numamukai area since about 1,300 years ago is discussed in following lines based on the pollen data. The age of each pollen zone was estimated by the age for To-a tephra and ^{14}C age of wood fragment included in peat

Table 2-2 Continue

Sample No.	Depth(cm)	Gramineae	Cyperaceae	*Typha*	*Persicaria*	*Polygonum*	*Rumex*	Chenopodiaceae	*Thalictrum*	Ranunculaceae	Rosaceae	Leguminosae	*Impatiens*	Haloragaceae	Umbelliferae	Labiatae	*Artemisia*	Carduoideae	Cichorioideae	Monolete Fern Spore	Trilete Fern Spore	Trees & Shrubs	Herbs	Ferns	Unknown	Total	Local Pollen Zone
1	215	470	165	9	3		1	7	1			1		3	1	1	21	5	9	37	9	342	697	46	94	1,179	NM-3
2	210	474	351	8	4	1		1	1			2		1	8		17	4	2	52	19	306	874	71	92	1,343	
3	205	104	206	4	3			1				1			5		41		1	15	8	311	366	23	56	756	
4	200	299	233	4	6							1		1	12		25	6	1	23	16	301	588	39	69	997	
5	195	376	225	5	5						1				20		27	7	2	31	26	301	668	57	63	1,089	NM-2
6	190	226	105	13	4							4			24		25	3		15	7	299	404	22	66	791	
7	185	176	90	7	1			1	3			1			7		50	2	2	69	15	304	340	84	64	792	
8	178	86	39	5	10					1	3	2		2	5	2	87			32	3	317	242	35	54	648	
9	168	53	29	13		1		1		2	1		1	1	1		10	1		30	4	310	114	34	50	508	
10	148	117	33	2	1	1					3		1	1	3		25	3		50	12	306	190	62	53	611	NM-1
12	140	56	32	1	1										2	1	37	1		20	10	314	131	30	43	518	
11	125	79	29	6	1										2		32	2		35	6	304	151	41	60	556	

Table 3-2 Continue

Sample No.	Depth(cm)	Gramineae	Cyperaceae	*Typha*	*Persicaria*	*Polygonum*	*Rumex*	Chenopodiaceae	*Thalictrum*	Ranunculaceae	Rosaceae	Leguminosae	*Impatiens*	Haloragaceae	Umbelliferae	Labiatae	*Artemisia*	Carduoideae	Cichorioideae	Monolete Fern Spore	Trilete Fern Spore	Trees & Shrubs	Herbs	Ferns	Unknown	Local Pollen Zone
1	215	39.9	14.0	0.8	0.3		0.1	0.6	0.1			0.1		0.3	0.1	0.1	1.8	0.4	0.8	3.1	0.8	29.0	59.1	3.9	8.0	NM-3
2	210	35.3	26.1	0.6	0.3	0.1		0.1	0.1			0.1		0.1	0.6		1.3	0.3	0.1	3.9	1.4	22.8	65.1	5.3	6.9	
3	205	13.8	27.2	0.5	0.4			0.1				0.1			0.7		5.4	0.1		2.0	1.1	41.1	48.4	3.0	7.4	
4	200	30.0	23.4	0.4	0.6							0.1		0.1	1.2		2.5	0.6	0.1	2.3	1.6	30.2	59.0	3.9	6.9	
5	195	34.5	20.7	0.5	0.5						0.1				1.8		2.5	0.6	0.2	2.8	2.4	27.6	61.3	5.2	5.8	NM-2
6	190	28.6	13.3	1.6	0.5							0.5			3.0		3.2	0.4		1.9	0.9	37.8	51.1	2.8	8.3	
7	185	22.2	11.4	0.9	0.1			0.1	0.4			0.1			0.9		6.3	0.3	0.3	8.7	1.9	38.4	42.9	10.6	8.1	
8	177.5	13.3	6.0	0.8	1.5					0.2	0.5	0.3		0.3	0.8	0.3	13.4			4.9	0.5	48.9	37.3	5.4	8.3	
9	167.5	10.4	5.7	2.6		0.2		0.2		0.4	0.2		0.2	0.2	0.2		2.0	0.2		5.9	0.8	61.0	22.4	6.7	9.8	
10	147.5	10.8	6.2	0.2	0.2										0.4	0.2	7.1	0.2		3.9	1.9	60.6	25.3	5.8	8.3	NM-1
12	140	19.1	5.4	0.3	0.2	0.2						0.5		0.2	0.2	0.5		4.1	0.5	8.2	2.0	50.1	31.1	10.1	8.7	
11	125	14.2	5.2	1.1	0.2										0.4			5.8	0.4	6.3	1.1	54.7	27.2	7.4	10.8	

bed.

Period of NM-1 (ca. 1,300~1,100 yrs BP)

Zone NM-1 is characterized by the high percentages for *Quercus*, *Fagus*, and *Carpinus*. During NM-1 time, the cool temperate deciduous broad leaved forest, consisting dominantly of *Quercus*, *Fagus*, and *Carpinus*, covered on the hilly lands, whereas, around the sampling site situated near the boundary between BR-1 and inner

back marsh, the grassland and shrubland composed mainly of Gramineae and of *Salix* respectively expanded.

Period of NM-2 (ca. 1,100~1,000 yrs BP)

A slight change of vegetation occurred in this area. The broad leaved forest composed chiefly of *Quercus*, *Fagus*, and *Carpinus* admixed with *Pinus* and *Cryptomeria* distributed in the hilly lands. An increase of *Pinus* and *Cryptomeria* seems to show a expansion of the secondary forest of *Pinus densiflora* and *Cryptomeria japonica* plantation. This change is inferred to have resulted from cutting down of such broad leaved trees as *Quercus* and *Fagus* and afforestation of *Cryptomeria* by ancient man. At the Numamukai site, rice paddy field remains have been discovered from a layer deposited in this period (Sendai City Board of Education, 2000). The existence of the rice paddy field remains and abundant Gramineae pollen grains indicates that rice paddy field cultivation began in the Numamukai area in this period.

Period of NM-3 (ca. 1,000 yrs BP~present)

Zone NM-3 characterized by high values for *Pinus*, *Cryptomeria*, and Gramineae pollen. The cool temperate broad leaved forest is inferred to have contracted by human impacts. On the other hand, the secondary forest of *Pinus densiflora* and *Cryptomeria japonica* plantation during this period more expanded than during the preceding period. It is considered that rice paddy field cultivation progressed conspicuously on the back march in the Numamukai area.

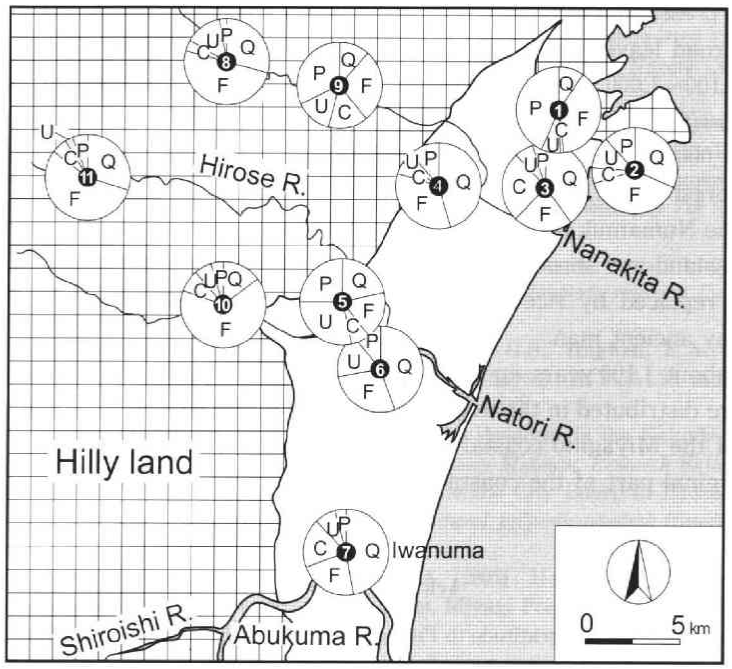
5.2 Vegetation in the northern part of the Miyagino coastal plain at about 1,100 years ago

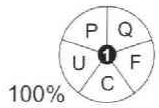
Many palynological studies of the deposits in and around the plain at about 1,100 years ago have been reported. Based on those data, percentages of major pollen taxa are shown in Fig. 4. Comparing the percentage of *Quercus* with that of *Fagus*, considerable difference is recognized in many places. *Quercus* is dominant at Localities 3, 6, and 7, *Quercus* and *Fagus* are almost the same at Localities 2, 4, and 5, and *Fagus* is dominant at Localities 1, 8, 9, 10, and 11.

From the survey of airborne pollen around Sendai City, Hibino and Yasuda (1973) clarified the relationship between airborne pollen and vegetation. According to them, the value of *Fagus* pollen is fairly high in the mountain region, but low in the hilly lands and the plain. Therefore, it is considered that these pollen grains are not spreaded far from their mother trees.

The vegetation in and around the northern part of the Miyagino coastal plain at about 1,200 years ago is given in the following lines based on the data just mentioned above.

The forest dominated by *Fagus* was distributed from the lower part of mountains to the upper part of hilly lands, whereas the forest in the plain was composed chiefly





❶ Loc.
Q: *Quercus*
F: *Fagus*
C: *Carpinus*
U: *Ulmus-Zelkova*
P: *Pinus*

1. Tagajyo (Yasuda, 1973) 2. Agawanuma (Omoto and Ouchi, 1978)
3. Numamukai (This study) 4. Kozuru (Omoto and Ouchi, 1978)
5. Yamaguchi (Yasuda, 1984) 6. Nakata minami (Morita, 1994)
7. Iwanuma (Takeuti *et al.*, 2005) 8. Nenoshiroishi (Miyagi *et al.*, 1979)
9. Akouzu (Takeuti, 1990) 10. Moniwa-Takada (Miyagi *et al.*, 1979)
11. Sakunami (Park, 2000)

Fig. 4 Map showing comparison with percentages of major pollen taxa about 1,100 yrs BP near the coastal plain

of *Quercus*. The area from the lower part of hilly lands to the marginal part of the plain is inferred to have been the transitional zone between two types of vegetation.

6. Conclusion

Comparing the result of pollen analysis of sediment samples obtained at Numamukai with other previous data, in following lines is given a brief summary.

1. From the result of pollen analysis, three local pollen zones, NM-1, NM-2, and NM-3 in ascending order, were established during a time interval from about 1,300

years ago to present. Period of NM-1 (ca. 1,300~1,100 yrs BP) is characterized by the temperate broad leaved forest dominated by *Quercus* and *Fagus*. During Period of NM-2 (ca. 1,100~1,000 yrs BP), the temperate broad leaved forest was locally replaced by *Pinus densiflora* secondary forest and *Cryptomeria japonica* plantation. Period of NM-3 (ca. 1,000 yrs BP~present) is characterized by expansion of *Pinus densiflora* secondary forest and *Cryptomeria japonica* plantation.

2. In the Numamukai area, rice paddy field cultivation was begun in Period NM-2. The grassland and shrubland composed chiefly of Gramineae and of *Salix* respectively were replaced by rice paddy field because of beginning of rice paddy field cultivation by ancient man.

3. At about 1,100 years ago, the forest composed mainly of *Fagus* and that of *Quercus* were distributed in the mountains and the upper part of hilly lands and in the main part of the Miyagino coastal plain, respectively. The lower part of hilly lands and the marginal part of the coastal plain were transitional zone.

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