Past vegetation on volcanic ash forest soil I

Pollen analysis of the Black soils, Brown fosest soils and Podzolic soil in Hakkoda mountain

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Summary : On the southern gentle slope of Takadaoodake, a peak of Hakkoda mountains, Black soil, Brown forest soil and Podzolic soil are distributed mosaic-like. In their soil profiles two obvious volcanic ash layers are interstratified. One of them is Towada-a-ash ejected in 1000 years B. P., the other is Chuseri pumice in 4000 years B. P. The A horizon with thickness of more than 10 cm develops on the Towada-a-ash layer and the buried A horizon with thickness of 20～30 cm also develops between two volcanic ash layers in the each soil.

In order to know the past vegetation of each soil, soil pollen analysis was made on the A horizon and the buried A horizon. The summary of the results is as follows.

(1) The limit of vertical downward migration of modern pollen was investigated under the man-made *Cryptomeria japonica* forest of 37 ages. The result shows that the influence of the penetration of modern pollen appears to a limit of 3 cm from the surface on pollen diagram.

(2) A relationship between the soil pollen flora from the upper parts of A horizon and the present vegetation was examined in each soil. In the results, the dominant genera of the upper parts of A horizon corresponded to those of the present vegetation on natural *Aesculus turbinata* forest, natural *Fagus crenata* forest, and old artificial *Cryptomeria japonica* forest. Whereas disaccords were recognized on artificial *Larix leptolepis* forest and young artificial *Cryptomeria japonica* forest. The disaccords concerning the latter seem to be caused by trees that were still young for flowering, whereas we couldn't make it clear about the former.

(3) In order to determine whether the fluctuation of soil pollen reflects the vegetational history, the pollen diagram of each soil was compared to that of the peal soil. The results of the comparison showed a fundamental similarity concerning the main anemophilous pollen e. g. *Fagus, Quercus, Cryptomeria, Pinus* and *Alnus*. Therefore it was considered that the pollen fluctuation in forest soils indicates the vegetational history as well as that of the peat soil.

(4) According to the soil pollen diagrams of each soil, it is concluded that the Black soil was covered by grass-land or open vegetation, whereas the Brown forest soil and Podzolic soil were covered by natural forests of *Fagus crenata* or *Aesculus turbinata* in the past.

1. Introduction

The mosaic distribution of volcanic Black soil, Brown forest soil and Podzolic soil is commonly observed on the gentle slope of volcanoes in Japan. These three soils are derived from the same volcanic ash.

One of the hypotheses concerning the genesis of these soils is that the Black soil may have been formed under grass-land vegetation whereas the Brown forest soil may have been formed under forest in the past. However a few researches on the relationship between soil genesis and past vegetation have been carried out.

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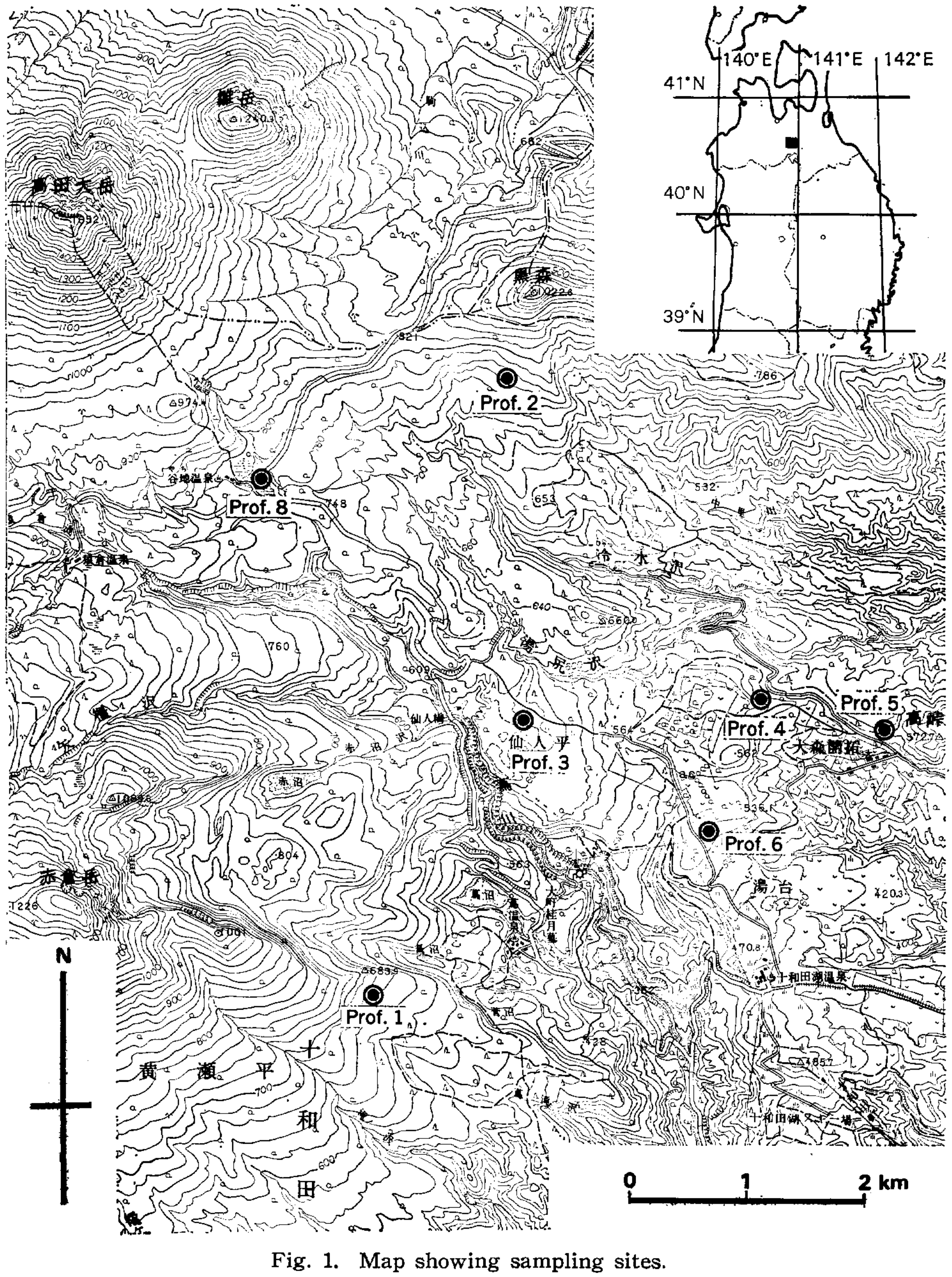

Fig. 1. Map showing sampling sites.

This paper has two purposes. The first is to investigate the relationship between soil genesis and past vegetation, and the second is to detect differences in past vegetation between Black soil and Brown forest soil by pollen analysis.

2. Study area and soils

The study area is situated at an elevation of 500 to 750 m on the southern gentle slope of Takadaoodake, a peak of the Hakkoda mountains (lat. 40°35′ N, long. 140°55′ E) (Fig. 1). According to Yoshioka and Kaneko[12], this area belongs to the montane zone of *Fagus crenata*. The soil types occurring in this area are Black soil, Brown forest soil, Podzolic soil and Peat soil, and they are distributed mosaic-like.

Two Black soils, three Brown forest soils, a Podzolic soil and a Peat soil were sampled for this study. The soil sampling sites are shown in Fig. 1. A brief description of site conditions such as elevation, slope and vegetation are shown in Table 1. Important morphological features of the soil profiles are summarized in Table 2.

As shown in Table 2 and Plate 1, two volcanic ash layers are interstratified in the soils. According to Oike[10], the grayish fine ash layer occurring at a depth of 10 to 20 cm is Towada-a-ash ejected from the Towada volcano in 1000 years B. P. The yellowish fine pumice layer occurring at a depth of 50 to 100 cm is Chuseri pumice in 4000 years B. P.

The buried A horizon develops between Towada-a-ash and Chuseri pumice in the each soils, and the A horizon with thickness of more than 10 cm also develops on the Towada-a-ash layer.

The A horizon of Prof. 5 soil was excluded from this study because it is ascertained to be formed by the construction work of forest road in the preceding year.

3. Method

The soils were sampled for pollen and chemical analysis by Soil Survey Manual for National Forest[1].

The chemical methods used were; pH (H_2O), potentiometrically in water (1 : 2.5) and total C and N, by the dry combustion method using Yanagimoto CN corder.

The soil pollen analysis used was as follows.

(1) 30 g of fresh soil was sampled into plastic vessels, added 5% KOH solution, and then allowed to stand overnight.

(2) Soils were stirred with a screw stirrer for 30 minutes, and sieved for removing coarse soil material.

(3) Soils were centrifuged in condition of 2000 rpm, 20 minutes, in order to remove humus and clay dispersed in the liquid. This centrifuging was repeated until the supernatant liquid was clear.

(4) Pollen grains were separated from the soil using $ZnCl_2$ with a specific gravity of 1.8, and then subjected at hot state to acetolysis during 10 minutes.

(5) The pollen grains and spores obtained were mounted in glycerin jelly.

(6) They were detected under a Nikon optiphoto pol type microscope, usually at a magnification of ×200 or ×400.

(7) The samples of modern pollen grains were obtained from living plants and prepared by the acetolysis method as a reference for identification of the fossil one during the process of microscopic examination.

Table 1. Site condition.

Prof No.	Soil type	Altitude (m)	Slope (°)	Topography	Vegetation
1	Brown forest soil (B_D type)	660	5	Flat on lava terrace sloping toward southeast	Natural forest of *Aesculus turbinata* with few *Fagus crenata*. The sub tree layer is mainly *Fagus crenata*. Shrub layer consists of *Fagus crenata*, *Aesculus turbinata*, *Hydrangea paniculata*, *Panax schinseng*, and *Anemone nikoensis*.
2	Podzolic soil ($P_{D\text{III}}$ type)	750	6	Gentle slope of lava flow facing toward south	Natural forest of *Fagus crenata*. Shrub layer consists of *Fagus crenata*, *Acanthopanax sciadophylloides*, *Acer japonicum*, *A. micranthum*, *Taxus cuspidata*, *Viburnum furcatum*, *Skimmia repens*, *Euonymus alata*, *Benzoin umbellatum* and *Rhus orientalis*.
3	Brown forest soil (B_D type)	605	0	Flat on lava terrace sloping toward south	Man-made forest of *Larix leptolepis* (50 ages). Shrub layer consists of *Magnolia obovata*, *Hydrangea macrophylla*, *Sasa kurilensis*, *Kalopanax septenlobus*, *Fagus crenata*, *Euonymus alata*, *Ilex crenata*, *Acer shirasawanum*, *Dryopteris crassirhizoma*, *Pteridium aquilinum* and *Carex* sp.
4	Brown forest soil	550	6	Gentle slope of lava facing toward east	Man-made forest of *Cryptomeria japonica* (37 ages). Uudergrowth is mainly *Dryopteris crassirhizona*.
5	Black soil (Bl_D(d) type)	500	0	Flat on lava terrace	Man-made forest of *Cryptomeria japonica*. Undergrowth is dominated by *Pteridium aquilinum*.
6	Black soil (Bl_D(d) type)	520	0	Flat on lava terrace sloping toward south	Man-made forest of *Cryptomeria japonica* (20 ages). Undergrowth consists of *Imperata cylindrica*, *Weigela hortensis* and *Pteridium aquilinum*.
8	Peat soil	740	0	Moor formed among the small streams	Moor vegetation consists of *Rhododendron japonicum*, *Ilex crenata*, *Sasa kurilensis*, *Phragmites communis*, *Eriophorum vaginatum*, *Lysichiton camtschacense*, *Drosera rotundifolia*, *Osmunda cinnamomea*, and *Lycopodium inundatum*.

Table 2. Some important properties of the soil samples.

Prof. No.	Soil type	Horizon	Depth (cm)	Soil color (moist)	T-C (%)	T-N (%)	C/N	pH (H_2O)
1	Brown forest soil (BD type)	A_0	(L : 2 cm, F : 1～2 cm)					
		A_1	0～10	10 YR 3/2	7.2	0.52	13.8	4.0
		A_2	10～15	7.5 YR 4/3	6.1	0.42	14.5	4.3
		To-a	15～20	7.5 YR 7/1	—	—	—	—
		ⅡA	20～40	7.5 YR 4/3	4.7	0.33	14.2	4.9
		Cu_1	40～45	10 YR 4/4	—	—	—	—
		Cu_2	45～95	10 YR 5/8	—	—	—	—
		ⅢA	95～105	7.5 YR 4/4	2.9	0.20	14.5	5.1
2	Podzolic soil (PDⅢ type)	A_0	(L : 2～3 cm, F : 2 cm, H : 1～2 cm)					
		A	0～10	10 YR 3/4	13.9	0.69	20.2	4.3
		B_1	10～11	7.5 YR 4/4	8.1	0.43	18.6	4.2
		To-a	11～14	10 YR 6/2	—	—	—	—
		ⅡA_1	14～30	10 YR 4/3	4.6	0.25	18.1	4.9
		ⅡA_2	30～45	10 YR 3/4	3.6	0.25	14.5	5.1
		Cu_1	45～47	10 YR 4/3	—	—	—	—
		Cu_2	47～65	10 YR 6/8	—	—	—	—
3	Brown forest soil (BD type)	A_0	(L : 1～2 cm)					
		A_1	0～5	7.5 YR 2.5/2	11.7	0.95	12.3	4.0
		A_2	5～15	10 YR 3/2	5.1	0.37	13.5	4.6
		To-a	15～24	2.5 Y 5/3	—	—	—	—
		ⅡA	24～60	10 YR 3/3	4.9	0.35	13.7	5.0
		Cu_1	60～65	10 YR 4/3	—	—	—	—
		Cu_2	65～110	10 YR 6/6	—	—	—	—
4	Brown forest soil (BD type)	A_0	(L : 2～3 cm, F : 1～2 cm)					
		A_1	0～6	7.5 YR 3/3				
		A_2	6～16	7.5 YR 4/4				
		To-a	16～20	7.5 YR 6/2				
		ⅡA	20～55	10 YR 4/3				
5	Black soil (BlD(d) type)	A_0	(L : 1～2 cm)					
		A	0～5	10 YR 4/2	—	—	—	—
		ⅡA_1	5～12	10 YR 2/1	7.3	0.34	21.5	5.1
		ⅡA_2	12～20	10 YR 3/1	8.7	0.36	24.2	5.3
		To-a	20～25	2.5 YR 6/3	—	—	—	—
		ⅢA	25～50	10 YR 3/3	5.9	0.38	15.5	5.4
		Cu_1	50～55	10 YR 4/3	—	—	—	—
		Cu_2	55～100	10 YR 6/8	—	—	—	—
		ⅣA	100～110	10 YR 4/4	3.8	0.22	17.3	5.5
6	Black soil (BlD(d) type)	A_0	(L : 1～2 cm, F : 0.5～1 cm)					
		A	0～14	10 YR 2/2	11.1	0.75	14.7	5.0
		To-a	14～22	2.5 YR 5/3	—	—	—	—
		ⅡA_1	22～43	10 YR 1.7/1	6.3	0.42	15.0	5.2
		ⅡA_2	43～55	10 YR 2/2	6.7	0.45	14.3	5.3
		Cu	55～110	7.5 YR 4/6	—	—	—	—

To-a : Towada-a-ash, Cu : Chuseri pumice.

(8) More than 200 arboreal pollen grains (AP) were counted as the basal number for computing the percentage in each preparations.

4. **Results and disscusion**

Frequency tables of pollen and spores were shown in Appendix-Table 1 to 7, and pollen diagrams were shown in Fig. 2 to 8. Microphotographs of the pollen and spores occuring in the soils were shown in Plate 2.

It has been known for a long time that forest soil contains a great deal of pollen and spores through the profile. But pollen analytical studies of forest soil were scarcely conducted except some (MIURA[7)~9)], ARAGANE[2)], KAWAMURO and TORII[4)~6)], DIMBLEBY[3)]). Consequently, pollen analysis of forest soil involves some important problems to be solved at present.

One of them concerns a vertical downward migration of pollen through the soil by a gravity water and biological activity. Occurrences of downward migration of pollen may bring about a mixing of modern and fossil pollen in the soil. It makes pollen analysis for the reconstruction of the past vegetation meaningless.

According to ARAGANE[2)], modern pollen was vertically migrated from surface to the part of 10 cm depth on a stratified grassland soil and a colluvial soil. In the result reported by MIURA[7)], the vertical migration of the *Sasa* pollen grains which were supplied by flowering three years before, was primarily confined to the topmost layers of the soil profile.

In order to know the vertical migration of modern pollen in the soil, we analyzed the soil samples under the artificial *Cryptomeria japonica* forest of 37 ages. A pollen diagram of this soil was shown in Fig. 5.

From this diagram, *Cryptomeria* shows a maximum frequency (84%) in the A_0 horizon, and then abruptly decreases to a depth of 3 to 6 cm in A_1 horizon.

Most pollen grains of *Cryptomeria,* which were contained in samples from surface to a 3 cm depth, may be legitimately considered as modern pollen grains derived from living trees of *Cryptomeria japonica* on the soil. But, those in samples from 3 to 6 cm depth and more lower parts may be considered as fossil pollen grains which were supplied from parent trees at an other region in the past. Because the same frequency of *Cryptomeria* pollen appeared to the same depth of peat sample (Prof. 8) and of other soil samples under the forest of *Fagus crenata* or *Larix leptolepis* (Prof. 1, 2 and 3). MIURA reported that the *Cryptomeria* pollen from the soils under the natural forest consisting of *Fagus crenata* or *Abies mariesii* in Hakkoda mountains

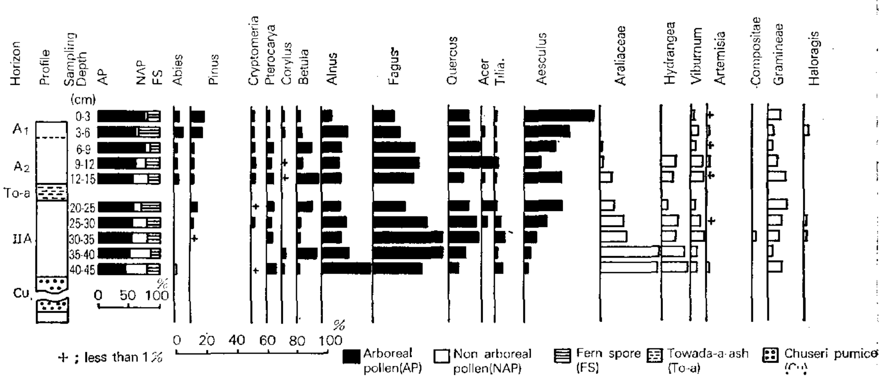

Fig. 2. Soil pollen diagram of the Brown forest soil of Prof. 1.

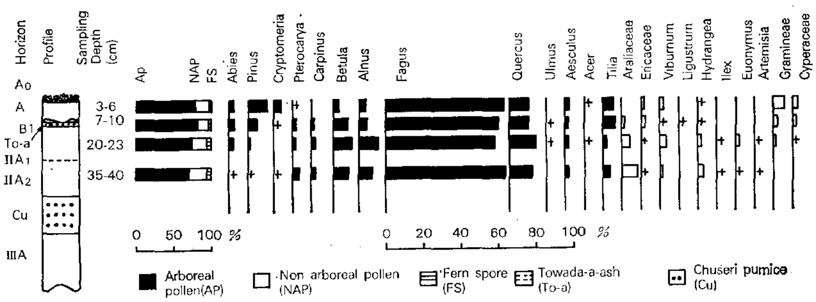

Fig. 3. Soil pollen diagram of the Podzolic Soil of Prof. 2.

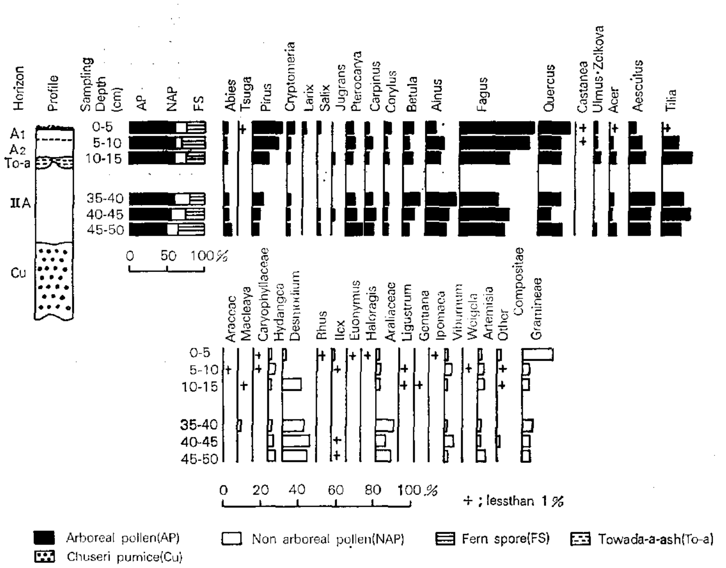

Fig. 4. Soil pollen diagram of the Brown forest soil of Prof. 3.

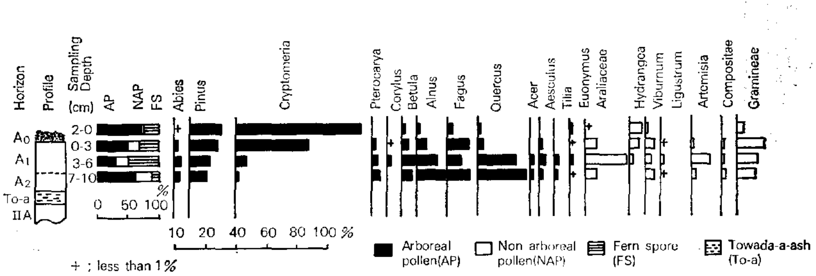

Fig. 5. Soil pollen diagram of the Brown forest soil of Prof. 4.

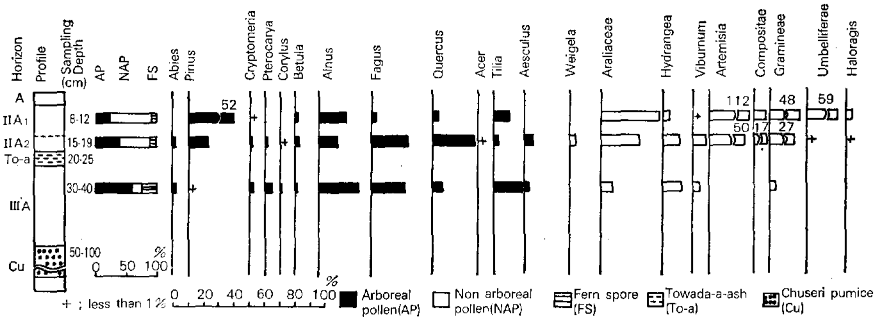

Fig. 6. Soil pollen diagram of the Black soil of Prof. 5.

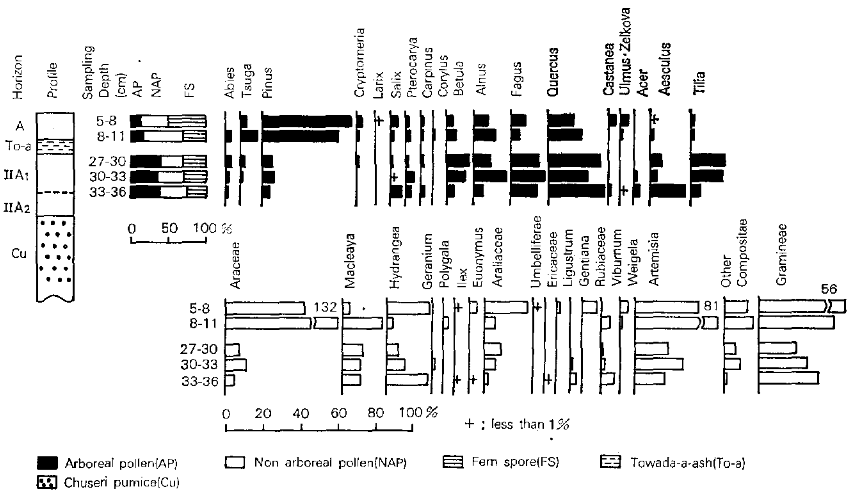

Fig. 7. Soil pollen diagram of the Black soil of Prof. 6.

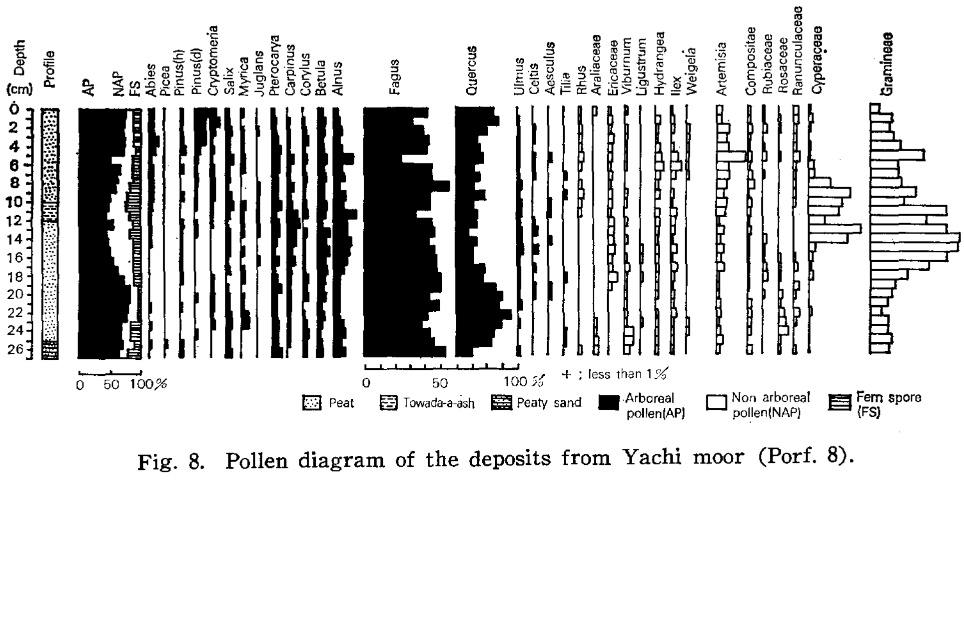

Fig. 8. Pollen diagram of the deposits from Yachi moor (Porf. 8).

maight be supplied from its forest at the foot of the mountains far below in the past[9]. Therefore, we can say that the influence of migration of modern pollen appears in only the upper parts of A horizon, and it does not appear in the other horizons on the soil pollen flora.

Subsequently, we summarized following table in order to establish a relationship between the soil pollen flora from upper parts of A horizon and the present vegetation on the soil.

Prof. No. and Soil type		Dominant pollen of upper parts of A horizon	Dominant species of present vegetation
Prof. 1	Brown forest soil	*Aesculus*, *Fagus*	*Aesculus turbinata*
Prot. 2	Podzolic soil	*Fagus*	*Fagus crenata*
Prof. 3	Brown forest soil	*Fagus*	*Larix leptolepis* (50 ages)
Prof. 4	Brown forest soil	*Cryptomeria*	*Cryptomeria japonica* (37 ages)
Prof. 5	Black soil	*Artemisia*, Gramineae	*Cryptomeria japonica* (20 ages)
Prof. 6	Black soil	*Artemisia*, Gramineae	*Cryptomeria japonica* (20 ages)

Dominant genera of the upper parts of A horizon were in accord with species of the present vegetation on Prof. 1, 2 and 4 soils. But they were out of accord with present vegetation on Prof. 3, 5 and 6 soils. Disaccords of Prof. 5 and 6 soils seem to be caused by the tree ages which were still too young for flowering. It was considered that *Artemisia* and Gramineae, dominant pollen in upper parts of A horizon of Prof. 5 and 6, might reflect the vegetation at planting time. The cause of disaccord in upper parts of A horizon of Prof. 3 under *Larix leptolepis* forest was not clarified however. There seems to be a tendency of *Larix* pollen to disappear in soils, because a small amount of *Larix* pollen was also detected in upper parts of A horizon under the *Larix leptolepis* forest in Mt. Kurohime[4] the same as Prof. 3 soil of this study.

Subsequently, in order to know whether the fluctuation of soil pollen through a profile was reflected by the vegetational history or not, the pollen diagram of each soil was compared to that of the peat soil (Prof. 8).

As mentioned above, two tephras, that is Towada-a-ash (1000 years B. P.) and Chuseri pumice (4000 years B. P.), were interstratified in the each soil. Two tephras were favorable to be used as the time index.

The results of comparison between the pollen fluctuation of forest soils (Prof. 1, 2, 3, 4, 5 and 6) and a Peat soil (Prof. 8) are as follows.

(1) From the pollen diagram of Peat soil (Prof. 8), *Fagus-Quercus* comunity has been continued around Prof. 8 site since the period of Chuseri pumice fall. Such an idea is also suported by the results obtained from the same moor in this mountain[11].

(2) On the pollen diagrams, the fluctuation patterns of *Abies*, *Pinus*, *Cryptomeria* and *Alnus* from the forest soils are similar to those from the Peat soil.

However, those of *Aesculus*, *Tilia*, Araliaceae,, *Artemisia*, other Compositae, Araceae, *Macleaya* and Umbelliferae are quite different from those of the Peat soil. A group of the former genera belongs to the anemophilous pollen which is widely scattered in the wind far away, but the latter belongs to the entomophilous pollen which is scattered nearby the parent tree. Therefore, it is considered that the former may reflect the vegetation of comparatively wide area whereas the latter may reflct that nearby parent tree.

The idea that the soil pollen assemblages could be divided into two groups by their natural characters had already been put forth by MIURA[7)9)]. He pointed out that there existed the same tendency as mentioned above on the pollen diagrams from many forest soils in Hakkoda mountains.

(3) It is considered that the pollen fluctuation of forest soils indicates the vegetational history as well as those of Peat soil, because the fluctuation pattern of *Abies, Pinus, Cryptomeria,* and *Alnus* from the forest soils are quite similar to those from the Peat soil.

Consequently, we reconstructed the following vegetation history on each soil.

(1) Prof. 1 Brown forest soil (B_D type)

The *Fagus-Quercus* comunity has been continued around this site from the period of Chuseri pumice fall to the present. A characteristic feature of the soil pollen diagram is that the high frequency of Araliaceae was recorded just after the Chuseri fall. It seems to indicate the possibility of growth of the sun plants such as *Aralia elata* and *Acanthopanax sciadophylloides* around this site during a certain period just after the Chuseri fall. And then, it is recognized that the increase of *Aesculus* occurs synchronously with the decrease of Araliaceae through the whole profile. From these facts, we assumed the vegetational developement of the sun plants occurred just after the Chuseri fall and was gradually replaced by the tolerant trees such as *Aesculus tubinata* in the site.

(2) Prof. 2 Podzolic soil (P_{DIII} type)

Fagus crenata forests just as same as the present vegetation has been continued during whole period around the site, because *Fagus* is overwhelmingly dominant through the pollen diagram.

(3) Prof. 3 Brown forest soil (B_D type)

The *Fagus-Quercus* comunity with *Betula, Alnus, Aesculus* and *Tilia* has been continued since the period of the Chuseri fall. But, the pollen assemblage of the parts higher than the Towada-a-ash layer is slightly differed from that of the parts lower than the layer because of the frequency of Araliaceae and *Desmodium.* The forest before the Towada-a-ash fall seems to be comparatively more open than that after the fall.

(4) Prof. 5 Black soil (Bl_D(d) type)

The distinct difference of pollen assemblage is recognized between the IIA horizon, higher than the Towada-a-ash layer and the IIIA horizon, lower than the same layer. The frequency of arboreal pollen from the IIA horizon is considerably lower than that from the IIIA horizon. The arboreal pollen from the IIIA horizon is mainly composed of *Fagus, Tilia* and *Alnus.* It indicates that there was a *Fagus crenata* forest with *Tilia* and *Alnus* around the site in the period until the Towada-a-ash fall. The pollen assemblage from the IIA horizon, however, is wholly dominated by the non-arboreal pollen mainly composed of *Artemisia,* Gramineae and Umbelliferae. This fact indicates that the grass land vegetation remained on the site for a long period after the Towada-a-ash fall.

(5) Prof. 6 Black soil (Bl_D(d) type)

Non-arboreal pollen is dominant through the profile, and its ratio to total pollen and spores increases toward the surface. Especially, the frequencies of the sun plants such as *Artemisia* and other Compositae is higher than others. From these facts, it is assumed that the grass land vegetation or the open vegetation have been continued around the site since the period of Chuseri pumice fall.

The vegetation histories on the previously mentioned soils are summarized as follows.

Soil and profile No.	Vegetation before the Towada-a-ash fall (4000~1000 years B. P.)	Vegetation after the Towada-a-ash fall (1000 years B. P.)	Present Vegetation
Brown forest soil, Prof. 1	*Fagus crenata* forest	*Aesculus turbinata* forest	*Aesculus turbinata* forest
〃 Prof. 3	*Fagus-Quercus* community forest	*Fagus-Quercus* community forest	**Larix leptolepis* forest
〃 Prof. 4	—	*Fagus-Quercus* community forest	**Cryptomeria japonica* forest
Black soil Prof. 5	*Fagus crenata* forest	Grass land or Open vegetation	**Cryptomeria japonica* forest
〃 Prof. 6	Grass land or Open vegetation	Grass land or Open vegetation	**Cryptomeria japonica* forest
Podzolic soil Prof. 2	*Fagus crenata* forest	*Fagus crenata* forest	*Fagus crenata* forest

(* man-made forest)

As mentioned above, the Brown forest soils and the Podzolic soil had been covered by the forest of *Fagus crenata* or *Aesculus turbinata* for a long time in the past, whereas the Black soils had been covered by the grass land or the open vegetation. However, the pollen assemblage from the IIIA horizon between Towada-a-ash and Chuseri pumice of the Black soil of Prof. 5 doesn't indicate the grass land or the open vegetation. Soil color of the IIIA horizon is dark brown, not black or brownish black. As pollen assemblage from the other black or brownish black A horizon indicates the grass land or the open vegetation, the black or brownish black A horizon seems to be closely related to the grass land or the open vegetation. Therefore it is considered that the Black soil with a black or brownish black A horizon may develope under the grass land or the open vegetation for a certain period in the past.

The sampling sites of the Black soils belong to the montane zone of *Fagus crenata* forest under the natural condition. Therefore it is impossible to explain except by accepting that a human or volcanic activity had occurred in the grass land or the open vegetation and continued around the site for a long period in the past. If the occurrence and continuance of the grass land or the open vegetation on the Black soils had been caused by the volcanic activity, the same vegetation might have occurred on the sites of Brown forest soils because these sites adjoined each other. According to YAMANAKA[11)], a synchronous abrupt increase of *Cryptomeria* and *Pinus* seems to begin at the period of Towada-a-ash fall because of the human activity below the montane zone in Hakkoda area. As the occurrence of the grass land or the open vegetation almost began at the period of Towada-a-ash fall on the Black soils, the occurrence of that also seems to be caused by the human activity in the past.

The descriptions and disscussions mentioned above are summarized as follows :

(1) We were able to reconstruct not only the vegetation history that occured in a certain wide area, but also that which occurred in very local area by the soil pollen analysis.

(2) It is concluded that the Black soils were covered by grass-land or open vegetation whereas the Brown forest soils and the Podzolic soil were covered by natural forests of *Fagus crenata* or *Aesculus turbinata* in the past.

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Explanation of Plate 1

No. 1 Brown forest soil (B_D type) of Prof. 3

No. 2 Vegetation on Prof. 3 soil, man-made forest of *Larix leptolepis* (50 ages)

No. 3 Black soil (Bl_D(d) type) of Prof. 6

No. 4 Vegetation on Prof. 6, man-made forest of *Cryptomeria japonica* (20 ages)

Explanation of Plate 2～4

No. 1 *Abies*, A horizon (7～10 cm) of Prof. 2
No. 2 *Abies*, IIA horizon (35～40 cm) of Prof. 3
No. 3 *Tsuga*, A horizon (8～11 cm) of Prof. 6
No. 4 *Pinus*, A horizon (7～10 cm) of Prof. 2
No. 5 *Pinus*, A_2 horizon (5～10 cm) of Prof. 3
No. 6 *Cryptomeria*, A_1 horizon (0～3 cm) of Prof. 4
No. 7 *Cryptomeria*, IIA horizon (35～40 cm) of Prof. 3
No. 8 *Pterocarya*, A_2 horizon (5～10 cm) of Prof. 3
No. 9 *Carpinus*, A_1 horizon (0～5 cm) of Prof. 3
No. 10 *Corylus*, A_1 horizon (0～5 cm) of Prof. 3
No. 11 *Betula*, A_1 horizon (0～5 cm) of Prof. 3
No. 12 *Betula*, IIA_1 horizon (20～23 cm) of Prof. 2
No. 13 *Alnus*, A_1 horizon (0～5 cm) of Prof. 3
No. 14 *Alnus*, A_1 horizon (0～3 cm) of Prof. 1
No. 15 *Fagus*, A horizon (7～10 cm) of Prof. 2
No. 16 *Fagus*, A_2 horizon (5～10 cm) of Prof. 3
No. 17 *Fagus*, IIIA horizon (30～40 cm) of Prof. 5
No. 18 *Quercus*, IIA_1 horizon (20～23 cm) of Prof. 2
No 19 *Quercus*, IIA horizon (35～40 cm) of Prof. 3
No. 20 *Ulmus* (*Zelkova*), A_2 horizon (10～15 cm) of Prof. 3
No. 21 *Aesculus*, A_2 horizon (10～15 cm) of Prof. 3
No. 22 *Aesculus*, A_1 horizon (3～6 cm) of Prof. 1
No. 23 *Tilia*, IIA_1 horizon (30～33 cm) of Prof. 6
No. 24 Araceae, A horizon (8～11 cm) of Prof. 6
No. 25 *Macleaye*, A horizon (8～11 cm) of Prof. 6
No. 26 Caryophyllaceae, A_1 horizon (0～5 cm) of Prof. 3
No. 27 Araliaceae, IIA horizon (40～45 cm) of Prof. 3
No. 28 Umbelliferae, IIA_2 horizon (30～40 cm) of Prof. 5
No. 29 *Gentiana*, IIA_1 horizon (30～33 cm) of Prof. 6
No. 30 *Viburnum*, A_1 horizon (0～5 cm) of Prof. 3
No. 31 Ericaceae, A horizon (7～10 cm) of Prof. 2
No. 32 *Weigela*, A horizon (5～8 cm) of Prof. 6
No. 33 *Artemisia*, IIA_2 horizon (15～19 cm) of Prof. 5
No. 34 *Artemisia*, IIA_1 horizon (27～30 cm) of Prof. 6
No. 35 Compositae, IIA_2 horizon (15～19 cm) of Prof. 5
No. 36 Compositae, A horizon (5～8 cm) of Prof. 6
No. 37 Compositae, A horizon (8～11 cm) of Prof. 6
No. 38 Gramineae, IIA_2 horizon (15～19 cm) of Prof. 5
No. 39 Gramineae, A horizon (5～8 cm) of Prof. 6
No. 40 *Lycopodium*, A_1 horizon (0～5 cm) of Prof. 3
No. 41 Monolete spore, IIA_1 horizon (27～30 cm) of Prof. 6
No. 42 Monolete spore, IIA_1 horizon (27～30 cm) of Prof. 6
No. 43 Trilete spore, A horizon (5～8 cm) of Prof. 6

火山灰に由来する森林土壌の過去の植被　第1報

—八甲田山の黒色土，褐色森林土および ポドゾルの花粉分析結果について—

河室公康[1]・鳥居厚志[2]

摘　　要

わが国の火山山麓には，同じ火山灰を母材としながら黒色土のほかに，褐色森林土およびポドゾルなどがモザイク状に分布する例が多い。黒色土の成因については，過去の植被が草原であったとする説がある。しかし，この黒色土草原説の検証を含めて，土壌の成因と過去の植被との関係を調べた研究は少ない。

筆者らは，八甲田山の高田大岳南麓緩斜面において，そこに分布する黒色土，褐色森林土，ポドゾルおよび泥炭土の花粉分析を行い，黒色土草原説の検証を試みた。

供試した各土壌断面中には，明瞭な2枚の火山灰層が認められる。その一つは約1,000年前に噴出したとされる十和田a火山灰であり，もう一つは約4,000年前に噴出したとされる中掫浮石である。十和田a火山灰の上には厚さが10cmを越えるA層が発達し，十和田a火山灰と中掫浮石との間には20〜30cmの埋没A層が発達する。このA層および埋没A層の花粉分析を行い，次の諸点について検討した。

(1)　37年生スギ人工林下で，現生スギ花粉の土壌中への沈下・侵入の状態を調べた。その結果，土壌の花粉組成中に現生スギ林の影響が見られたのは表層下3cmまでであった。

(2)　各供試土壌の現植被と表層土（A層上部）の優勢花粉との関係を調べた。

その結果，トチノキ天然林，ブナ天然林および樹齢の高いスギ人工林の現植被と表層上の優勢花粉との関係は一致したが，樹齢の低いスギ人工林およびカラマツ人工林では一致しなかった。

樹齢の低いスギ人工林については，未だ開花時期に到っていないためと考えられたが，カラマツ人工林下でカラマツ花粉が優勢でない理由については明らかにしえなかった。

(3)　各供試土壌の花粉組成が過去の植被変遷を反映したものであるかどうかを検討するために土壌の花粉ダイアグラムと泥炭のそれを比較した。

その結果，各土壌の *Fagus*, *Quercus*, *Pinus*, *Cryptomeria* および *Alnus* などの風媒花粉は，泥炭とまったく類似の出現傾向を示した。八甲田山に数多く在る泥炭の各花粉分析結果において同じ時代の *Pinus*, *Cryptomeria* および *Alnus* の花粉出現傾向は基本的に一致しており，土壌のそれも同様であったことから土壌花粉も泥炭と同様に過去の植被変遷を反映したものと考えられた。

(4)　各供試土壌の花粉ダイアグラムからそれぞれの土壌の過去4,000年の植被を推定した結果，褐色森林土とポドソルのそれは一貫してブナ林もしくはトチノキ林であったが，黒色土のそれは疎林もしくは草原であったことが分かった。

1985年12月21日受理
(1) (2)　土　壌　部

Appendix-Table 1. Frequency (%) table of pollen and spores from the Prof. 1 (Brown forest soil).

Pollen	Horizon & Sampling depth (cm)									
	A_1		A_2			II A_1				
	0～3	3～6	6～9	9～12	12～15	20～25	25～30	30～35	35～40	40～45
Abies	3	6	1	1	3					1
Pinus	10	7	2	3	1	5	2	1		
Cryptomeria	1	1	1	2	3	1	2			1
Pterocarya	1	1	5	4	4	5	2	3		10
Carpinus	1						1	+		
Corylus	1	1		+	+			2	1	
Betula	3	3	9	5	14	10	2	3	13	1
Alnus	7	17	13	12	13	12	16	12	18	37
Fagus	14	19	28	30	27	21	36	46	46	33
Quercus	13	14	20	21	9	13	18	19	11	7
Castanea									5	
Ulmus-Zelkova				1						1
Acer		1	+	7	1	8	3			
Aesculus	44	29	20	12	24	24	14	7	4	3
Tilia	2	1	1	2	1	1	4	7	2	6
Σ AP	100	100	100	100	100	100	100	100	100	100
100 Σ AP/Σ(AP+NAP+FS)	73	56	75	60	55	55	53	54	52	42
Hydrangea				10	8	4	11	10	15	19
Ilex		+								
Haloragis		3		+			1	1		
Araliaceae			+	2	7	9	15	17	40	38
Ligustrum			+							
Viburnium	2	5	2	8	9	2	6	9	4	4
Artemisia		2	+	1	+		+			3
Other Compositae			2							
Gramineae	7	5	2	8	14	13	12	9	4	15
Σ NAP	9	15	6	29	38	28	45	46	63	121
100 Σ NAP/Σ (AP+NAP+FS)	7	9	7	18	21	15	24	25	33	33
Monolete spore	26	63	24	35	37	48	42	38	28	58
Trilete spore	+	2	18	3	7	6	2	2		1
Σ FS	27	65	42	38	44	54	44	40	28	59
100 Σ FS/Σ (AP+NAP+FS)	20	35	18	22	24	30	23	21	15	25
Non descript	5	3	4	2	11	8	7	13	21	35
Non desc./total	3	1	3	1	6	4	4	7	10	12
Total grains	(405)	(544)	(300)	(542)	(355)	(368)	(323)	(299)	(305)	(220)

total grains are numbers of counted grains. AP : arboreal pollen, NAP : non-arboreal pollen, FS : fern spore, + : less than 1 percent.

Appendix-Table 2.
Frequency (%) table of pollen and spores from the Prof. 2 (Podzolic soil).

Pollen	Horizon & Sampling depth (cm)			
	A		II A1	II A2
	3〜6	7〜10	20〜23	35〜40
Abies	1	2	1	+
Pinus	10	5	1	
Cryptomeria	4	+		+
Pterocarya	+	2	1	3
Carpinus		1	2	2
Corylus		1	2	+
Betula	3	8	9	8
Alnus	3	4	10	7
Fagus	63	60	58	64
Quercus	10	10	14	12
Castanea		+		
Ulmus-Zelkova		+	+	
Acer	+		+	
Aesculus	1	1	1	1
Tilia	5	6	1	3
Σ AP	100	100	100	100
100 Σ AP/Σ (AP+NAP+FS)	87	88	82	79
Hydrangea	+	+	1	3
Ilex			+	+
Euonymus			1	+
Araliaceae		+	4	8
Ericaceae	1	2	+	+
Ligustrum		+		
Viburnum	2	+	3	1
Artemisia		+	+	
Gramineae	6	2	1	
Σ NAP	11	6	12	13
100 Σ NAP/Σ (AP+NAP+FS)	9	6	10	10
Monolete spore	4	5	10	12
Trilete spore	+	2		1
Σ FS	4	7	10	13
100 Σ FS/Σ (AP+NAP+FS)	4	6	8	9
Non descript	8	5	9	11
Non desc./total	7	4	7	8
Total grains	(383)	(409)	(481)	(438)

total grains are numbers of counted grains.

Appendix-Table 3.
Frequency (%) table of pollen and spores from the Prof. 3 (Brown forest soil)

Pollen	Horizon & Sampling depth (cm)					
	A_1	A_2		II A		
	0〜5	5〜10	10〜15	35〜40	40〜45	45〜50
Abies	2	1	2	2	3	4
Tsuga	+					
Pinus	15	13	8	5	4	3
Larix	1					
Cryptomeria	3	1	1	1	1	1
Salix	1				1	1
Juglans			1		1	
Pterocarya	3	4	3	4	5	8
Carpinus	1	3	1	3	5	4
Corylus	3	1	2	2	1	2
Betula	5	3	5	9	6	3
Alnus	5	9	8	16	12	11
Fagus	39	37	26	20	26	23
Quercus	17	11	12	11	7	13
Castanea	+	+				1
Ulmus-Zelkova	1	1	3			1
Acer	+	1	3	2	1	3
Aesculus	4	7	9	14	12	12
Tilia	+	8	16	11	15	10
Σ AP	100	100	100	100	100	100
100 Σ AP/Σ (AP+NAP+FS)	58	57	61	60	56	49
Araceae		+				
Macleaya			1	+		
Caryophyllaceae	+	+				
Hydrangea	1	4	2	1	3	4
Desmodium	1		10	11	14	13
Rhus	+					
Ilex	1	+			+	+
Euonymus	+				+	+
Harolagis	+					
Araliaceae	1	2	2	9	5	8
Ligustrum		+				
Gentiana			+			
Ipomoea	+					
Viburnum	2	4	2	1	5	2
Weigela		+				
Artemisia	1	3	3	2	2	4
Other Compositae	2	+	+		1	
Gramineae	16	3	3	5	4	4
Σ NAP	27	18	23	29	34	35
100 Σ NAP/Σ (AP+NAP+FS)	16	10	14	18	19	17
Monolete spore	37	51	38	36	40	62
Trilete spore	8	7	3	2	5	8
Σ FS	45	58	40	38	45	70
100 Σ FS/Σ (AP+NAP+FS)	26	33	25	22	25	34
Non descript	46	23	14	44	14	32
Non desc./total	21	12	8	21	7	14
Total grains	(660)	(833)	(545)	(541)	(636)	(586)

total grains are numbers of counted grains.

Appendix-Table 4.
Frequency (%) table of pollen and spores from the Prof. 4 (Brown forest soil)

Pollen	Horizon & Sampling depth (cm)			
	A_0	A_1		A_2
	+2～0	0～3	3～6	7～10
Abies	+	2	6	3
Pinus	10	18	13	11
Cryptomeria	84	47	7	1
Juglans				1
Pterocarya		2	4	5
Corylus		+	2	+
Betula	1	5	10	6
Alnus	1	7	13	19
Fagus	3	14	9	14
Quercus	1	4	25	32
Castanea			+	
Ulmus-Zelkova			+	1
Acer			2	1
Aesculus		1	6	4
Tilia			3	2
Σ AP	100	99	100	100
Σ AP/Σ (AP+NAP+FS)	69	47	29	63
Cyperaceae			2	1
Hydrangea		7	6	2
Rhus			+	
Ilex			2	
Euonymus	1	+	3	+
Haloragis		1	+	1
Araliaceae	1	10	28	9
Umbelliferae			+	
Ericaceae			+	
Ligustrum		+	1	+
Gentiana			1	
Viburnum	1	6	4	6
Artemisia		1	12	4
Other Compositae		1	1	1
Gramineae	4	18	13	12
Σ NAP	7	45	74	38
100 Σ NAP/Σ (AP+NAP+FS)	4	21	21	24
Monolete spore	33	64	158	18
Trilete spore	6	6	16	2
Σ FS	39	70	174	20
100 Σ FS/Σ (AP+NAP+FS)	27	32	50	13
Non descript	5	5	3	2
Non desc./total	3	2	1	2
Total grains	(293)	(509)	(645)	(401)

total grains are numbers of counted grains.

Appendix-Table 5.
Frequency (%) table of pollen and spore from the Prof. 5 (Black soil)

Pollen	Horizon & Sampling depth (cm)		
	IIA_1	IIA_2	IIIA
	8～12	15～19	30～40
Abies		2	3
Pinus	52	13	+
Cryptomeria		2	4
Pterocarya		2	7
Corylus		+	1
Betula	2	3	2
Alnus	18	12	24
Fagus	5	24	26
Quercus	4	28	7
Castanea	9	3	+
Ulmus-Zelkova		2	+
Acer		+	
Aesculus		6	3
Tilia	10	2	22
Σ AP	100	99	99
100 ΣAP/Σ (AP+NAP+FS)	24	37	58
Cyperaceac	2	1	+
Hydrangea	5	12	13
Geranium	2		+
Rhus		1	
Euonymus	+	2	
Haloragis	4	+	+
Araliaceae	39	25	8
Umbelliferae	59	+	
Ericaceae	1	3	
Viburnum	+	10	5
Weigela		3	
Artemisia	112	49	1
Other Compositae	8	7	
Gramineae	28	27	5
Σ NAP	281	139	33
100 Σ NAP/Σ (AP+NAP+FS)	66	52	19
Monolete spore	30	23	37
Trilete spore	12	7	1
Σ FS	42	30	38
100 Σ FS/Σ (AP+NAP+FS)	10	11	23
Non discript	9	4	9
Non desc./total	2	1	5
Total grains	(732)	(712)	(474)

total grains are numbers of counted grains.

Appendix-Table 6. Frequency (%) table of pollen and spores from the Prof. 6 (Black soil)

Pollen	Horizon & Sampling depth (cm)				
	A		IIA_1		
	5～8	8～11	27～30	30～33	33～36
Abies		3	3	2	1
Tsuga	3	9	2	1	
Pinus	47	40	5	6	4
Larix	+				
Cryptomeria	3	1	1		
Cupressaceae		+			
Salix	4	1	1	+	6
Pterocarya	1	2	1	4	3
Carpinus	1	1	1		2
Corylus		1			
Betula	3	5	10	8	4
Alnus	8	12	9	18	5
Fagus	8	5	15	18	14
Quercus	13	17	28	21	31
Castanea	4				1
Ulmus-Zolkova	4	1			+
Acer				1	3
Aesculus	+	1	6	4	20
Tilia	1	1	18	17	5
Σ AP	100	100	100	100	99
100 Σ AP/Σ (AP+NAP+FS)	14	17	40	36	38
Araceae	42	132	7	11	5
Macleaya	4	21	11	10	10
Hydrangea	23	3	9	11	22
Geranium				1	
Polygala		3			
Ilex	+				+
Euonymus	4				+
Araliaceae	23	6	9	6	2
Umbelliferae	+				
Ericaceae					+
Ligustrum	2				
Gentiana				1	3
Rubiaceae	8				
Viburnum		5	1	2	7
Weigela	5	2			
Artemisia	34	81	18	25	16
Other Compositae	12	17	5	8	1
Gramineae	56	40	20	26	32
Σ NAP	213	310	80	101	98
100 Σ NAP/Σ (AP+NAP+FS)	34	54	32	37	38
Monolete spore	69	73	54	59	47
Trilete spore	286	92	16	15	17
Σ FS	355	165	70	74	64
100 Σ FS/Σ (AP+NAP+FS)	51	29	28	27	24
Non descript	38	61	124	101	74
Non desc./total	5	9	33	26	22
Total grains	(1, 155)	(979)	(764)	(710)	(645)

total grains are numbers of counted grains.

Appendix-Table 7-1. Frequency (%) table of pollen and spores from the Prof. 8 (Yachi moor).

Pollen	Sampling depth (cm)									
	1～0	1～2	2～3	3～4	4～5	5～6	6～7	7～8	8～9	9～10
Abies	3	3	4	6	4	2	4	3	3	3
Picea										
Tsuga										
Pinus (h)	1	1	1	2	3	1	2	1	1	2
Pinus (d)	10	7	7	7	4	3	1	2	1	2
Cryptomeria	5	6	3	1	2	1	2	2	3	2
Salix	1	2	3	3	3	6	2	2	2	3
Myrica	1		1	1	1	2	2			
Juglans	+		1			+	+		1	1
Pterocarya	2	3	4	4	6	6	6	5	4	4
Carpinus	+	2	1	1	1	4	2	1	3	2
Corylus	+	1	2	5	1	2	1	2	1	1
Betula	3	6	4	3	4	7	5	5	5	4
Alnus	4	4	5	4	7	16	7	8	5	9
Fagus	43	33	41	46	46	28	50	49	59	47
Quercus	27	31	21	15	16	19	14	16	11	19
Castanea		+			+		+			
Ulmus-Zelkova	+	1	1	1	2	1	1	1	2	1
Celtis-Aphananthe			1	1	+	1	1	1		
Aesculus	+	+	+	+	+	3			+	+
Stewartia			+							
Tilia				+			+	1		1
Σ AP	100	100	100	100	100	102	100	99	101	101
100 Σ AP/Σ (AP+NAP+FS)	73	64	61	63	60	44	59	58	54	44
Cyperaceae	1	2	1	+	1	1	3	4	15	30
Liliaceae	+									
Chenopodiaceae	1	+	+	1		2	1			1
Caryophyllaceae			+	+						
Ranunclaceae	3	3	2	2	3	5	+	2	1	2
Droseraceae		+								
Hydrangea	1	2	2	+	2	5	2	3	+	2
Rosaceae		1	1			1				
Rhus	1	1	2	2	2	4	3	+	2	3
Ilex	+	3	3	2	4	4	7	4	2	3
Viola	1		1		1	1		+	+	+
Hypericum		+	1	+	1	1		1		+
Haloragis		1	1	+	+			1		
Araliaceae	1	+							+	
Umbelliferea	+		1			1		+		
Ericaceae	1	2	1	3	2		1	2	2	2
Shortia			3	4	4	7	3	3	3	3
Symplocos	+						+			+
Labiatae		1	+	1	1	1	1		+	1
Rubiaceae	1	1	2		1	2	+	1	+	
Viburnum	1	+	1	1	1	1	+	1		+
Weigela	+	+	1	1	1	1	1	1	+	
Artemisia	3	4	8	7	9	23	9	9	7	5
Other Compositae	2	2	3	2	2	4	2	3	4	1
Gramineae	6	15	14	17	23	41	22	19	19	33
Σ NAP	23	38	47	44	57	102	54	52	57	86
100 Σ NAP/Σ (AP+NAP+FS)	17	24	29	28	34	45	32	30	31	38
Monolete spore	9	11	10	10	7	13	11	15	16	21
Trilete spore	5	7	5	4	4	10	4	6	11	20
Σ FS	14	19	16	14	11	23	14	21	28	41
100 Σ FS/Σ (AP+NAP+FS)	10	12	10	9	6	11	9	12	15	18
Total grains	(465)	(520)	(565)	(534)	(557)	(743)	(571)	(564)	(585)	(740)

total grains are numbers of counted grains.

Appendix-Table 7-2. (Continued)

Pollen	Sampling depth (cm)									
	10～11	11～12	12～13	13～14	14～15	15～16	16～17	17～18	18～19	19～20
Abies	2	1	1	1	1	+	+			+
Picea	+						+			
Tsuga					1					
Pinus (h)	1		1		1	1	1	1	1	+
Pinus (d)	1	+	1	1					+	
Cryptomeria	2	1	1		+			+	1	2
Salix	4	2	1	2	2	2	1	3	+	2
Myrica	2		1	1	2	1	+	1	1	
Juglans	2	1	1	1	+		1	+	+	+
Pterocarya	5	3	6	5	4	2	4	2	3	5
Carpinus	3	7	9	5	6	4	6	3	2	1
Corylus	2	4	+	2	1	1	1	1	4	2
Betula	6	6	2	8	5	7	6	6	5	3
Alnus	8	17	10	10	13	11	10	8	4	4
Fagus	46	37	48	50	45	51	53	52	57	52
Quercus	12	16	15	9	14	12	13	19	19	26
Castanea		1			+		1	1	1	+
Ulmus-Zelkova	2	2	1	2	3	3	1	1	1	1
Celtis-Aphananthe	+	+	1	2	1	3	+	1		2
Magnolia				+	+				+	
Acer				+			+	+		
Aesculus	1	1	+		1	+	+			1
Tilia	+		+				+		1	
Σ AP	99	99	99	99	100	98	98	99	100	101
100 Σ AP/Σ (AP+NAP+FS)	45	40	50	40	44	46	50	54	57	73
Polygonceae						+				
Cyperaceae	22	22	46	37	26	4	3	1	3	
Liliaceae									+	
Chenopodiaceae	+	+	1		+		+		+	
Ranunclaceae	1	1	+			+	1	2		3
Droseraceae									+	
Hydrangea	2	4	4	2	3	2	4	1	4	2
Rosaceae					+		1	1	1	+
Rhus	1	1	+			+	+		+	+
Ilex	2	3	3	2	1	2	2	2	2	2
Viola	2	1	1			+	1	3	2	
Hypericum			+		1	+	1			1
Haloragis				+						
Euonymus							+		+	
Umbelliferae		1		+	+			+	1	
Ericaceae	2	1	3	4	2	4	3	3	5	1
Shortia	2	5	5	4	4	4	3	3		3
Symplocos				+		+				
Labiatae						1	1	+	+	+
Labiatae	1	3	1	1	2	1	1	3	4	
Viburnum	1	1	+	1	+	1	1	3	2	1
Artemisia	7	7	1	5	2	5	4	4	1	1
Other Compositae	3	2	1	2	1	1	1	1	1	1
Gramineae	24	57	40	55	63	63	56	42	29	17
Σ NAP	71	110	74	114	105	91	83	70	57	32
100 Σ NAP/Σ (AP+NAP+FS)	30	44	37	45	47	42	41	37	32	24
Monolete spore	31	14	13	19	10	19	15	15	16	3
Trilete spore	22	27	11	19	12	8	4	1	3	1
Σ FS	54	41	25	38	21	27	19	16	18	4
100 Σ FS/Σ (AP+NAP+FS)	24	16	12	15	9	12	9	9	11	3
Total grains	(699)	(739)	(563)	(706)	(696)	(638)	(563)	(555)	(524)	(449)

total grains are numbers of counted grains.

Appendix-Table 9-3. (Continued)

Pollen	Sampling depth (cm)						
	20～21	21～22	22～23	23～24	24～25	25～26	26～27
Abies		1		1		1	
Picea						1	+
Pinus (h)		1	+	+	1	2	1
Pinus (d)	1			+	1		
Cryptomeria	2	2	2	2	+		
Salix	2	2	3	3	2	2	3
Myrica	1	1	4				
Juglans	+		+				
Pterocarya	3	3	3	4	4	4	7
Carpinus	3	2	2	2	1	1	
Corylus	3	+	1	2	4	2	3
Betula	5	2	4	3	1	3	4
Alnus	5	4	4	7	8	5	8
Fagus	43	50	42	41	48	52	59
Quercus	31	29	36	32	28	26	13
Ulmus-Zelkova	1	2		1	+		1
Celtis-Aphananthe	+	1	+				+
Acer					1		1
Aesculus	1	+		+			
Tilia	+	+	+		1	1	
Σ AP	101	100	101	98	100	100	100
100 Σ AP/Σ (AP+NAP+FS)	73	77	76	62	60	64	58
Polygonaceae			+				
Typhaceae						+	
Cyperaceae	+	+	1			+	+
Liliaceae				+			
Chenopodiaceae	+	1			1	1	
Ranunclaceae	1	1	3	2	+		2
Droseraceae	+						
Hydrangea	1	2	1	3	2	1	1
Rosaceae	3	1	3	4	7	3	3
Rhus			+	+		+	1
Ilex	2	+	1	3	2	2	2
Viola	1	1	+	1	1	2	1
Hypericum	1	1	2	5	3	2	3
Euonymus				+			
Araliaceae				1	1	3	2
Umbelliferae				+		+	1
Ericaceae		+	+	1	1	1	3
Shortia	2		1	2	1		2
Ligustrum	+	+	+	1		+	+
Labiatae	1	+	+	+	1	+	1
Rubiaceae							+
Viburnum	1	1	1	1	6	6	3
Weigela				1	1		+
Artemisia	1	2	2	1	2	3	2
Other Compositae	+	1	2	1	2	+	3
Gramineae	14	12	7	12	13	15	14
Σ NAP	29	24	25	40	46	41	45
100 Σ NAP/Σ (AP+NAP+FS)	23	19	19	24	28	27	26
Monolete spore	4	3	4	17	18	11	24
Trilete spore	1	2	3	6	3	3	4
Σ FS	5	5	7	23	21	15	29
100 Σ FS/Σ (AP+NAP+FS)	4	4	5	14	12	9	16
Total grains	(423)	(435)	(429)	(514)	(465)	(464)	(473)

total grains are numbers of counted grains.

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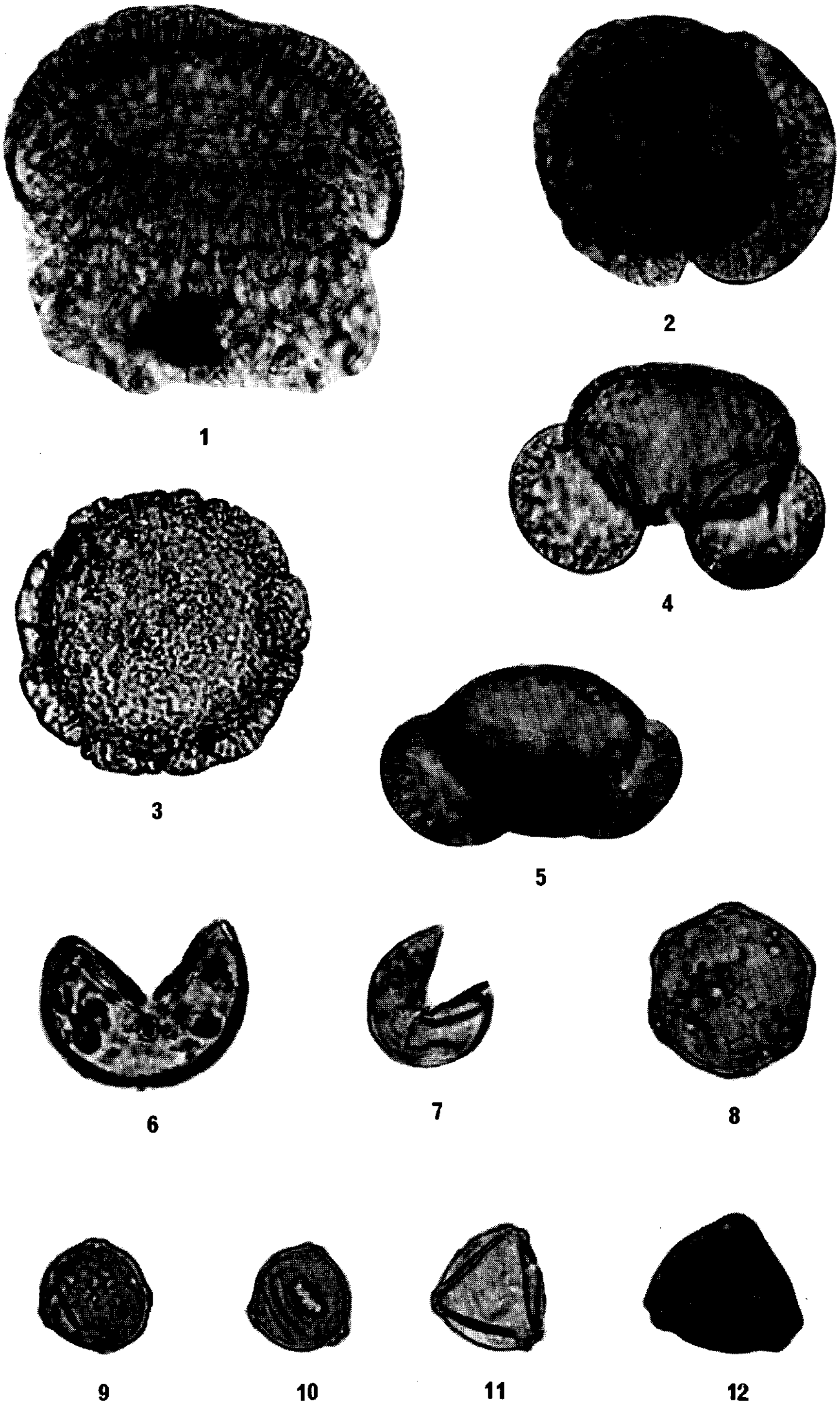
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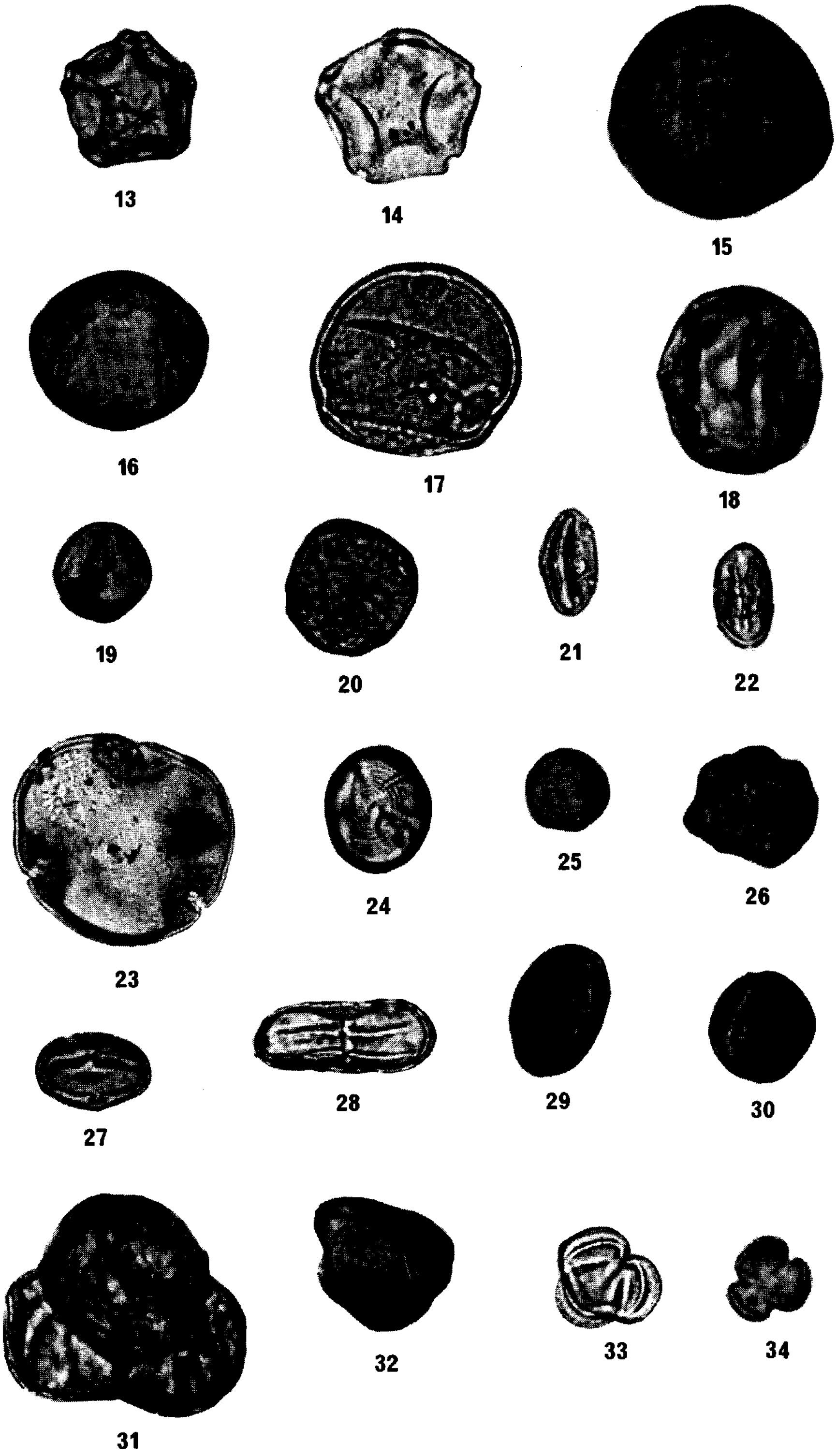
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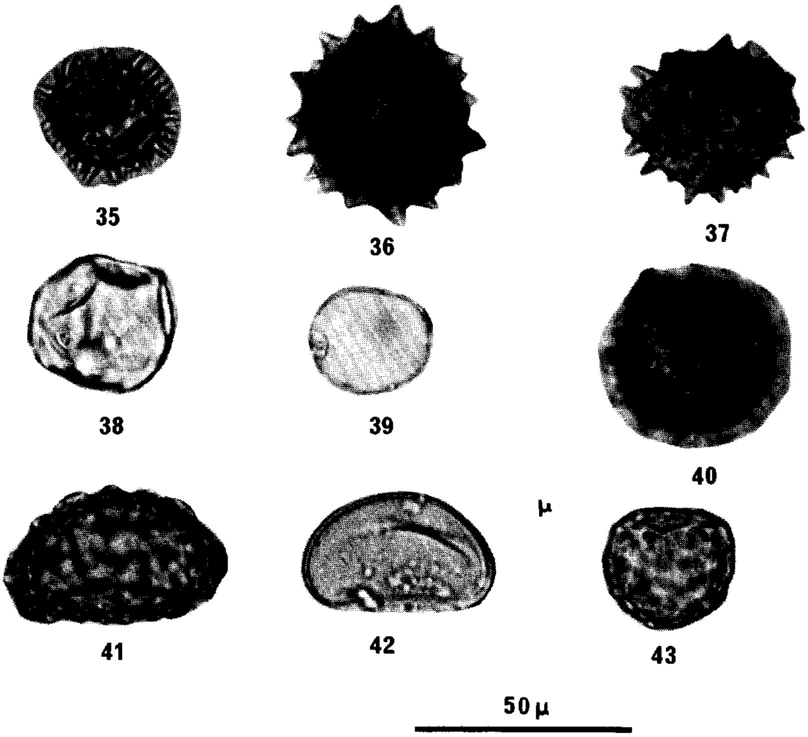
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