Hillslope Development under Changing Environment since 20000 years B.P. in Northeast Japan

著者	MIYAGI Toyohiko, HIBINO Koichiro, KAWAMURA Tomoko, NAKAGAWA Kyoji
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Hillslope Development under Changing Environment since 20,000 years B.P. in Northeast Japan

Toyohiko MIYAGI*, Koichiro HIBINO**, Tomoko KAWAMURA***
and Kyoji NAKAGAMI****

1 Introduction

Little has been worked on history of slope development under environmental changes of late Quaternary in humid temperate area like Japanese islands. It is caused by basic character of erosional landform, which the products is removed by erosion. Tamura and Miura (1968, 1971), Higaki (1981) had clarified the periods of slope instability by the method of tephrochronological and stratigraphic approach to the relation of slope deposits and tephra, in the Kitakami massif, northeast Japan. But the tephra is especially unstable on the slope in itself, so these data is not always applicable for the general hillslope in other areas.

The main erosional processes of hillslope in humid temperate area are various massmovements (Tamura 1974) such as failure, landslide and soil creep *etc.*, and micro-landform of hillslope is recognized by assemblage of aforesaid massmovements topography (Moriya 1972, Miyagi 1978). Accordingly, it is necessary to clarify the relationship in massmovement processes, especially between the occurrence of slope failures and the environmental changes. The northeast Japan is humid temperate area now, but in the last glacial age, here was southern boundary of the periglacial area (Suzuki 1962). The timber line was down about 1,000–1,500 m, and the temperature was down about 6–9°C in the last glacial age (Kaizuka 1968). We easily expect that the massmovement process changes with this climatic change.

Structural analysis of slope deposits has been done at four depressions in northeast Japan. These depressions are wholly enclosed by hillslope, and peat lands have developed on the bottom. We try to clarify the relationships between hillslope conditions (hillslope instability) and environmental changes during the last 21,000 years. Though this research is still continuing we have reached certain conclusions.

Tamura (1969, 1974) said, hillslopes with adequate soil and vegetation cover

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* Tohoku Gakuin Univ., Sendai
** Miyagi Agricultural College, Sendai
*** KK. Cine-Science
**** Tokyu Kanko KK.

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in humid temperate zone, may be composed of five micro-landform units, *i.e.* Crest slope, Side slope, Head hollow, Head floor and Channelway. These micro-landform units have particular hydrological conditions and dominant geomorphological processes, for example, Side slope and Head hollow have failures, Crest slope has soil creeping.

On the other hand, Hack and Goodlett (1960) observed in Appalachians in U.S.A., the close relationship between micro-landform units and vegetation, Miura and Kikuchi (1978) and Makita *et al.* (1979) also observed near Sendai in northeast Japan, the close relationship between micro-landform units after Tamura (1969, 1974) and vegetation, *i.e. Abies firma* and *Fagus crenata* stand on the Crest slope. On the other hand *Carpinus tschonoskii*, *C. laxiflora*, *Zelkova serrata* and *Fraxinus* are situated on the Side slope. *Ulmus davidiana* stands with failure deposits on the Head floor, natural lebee along little channels, and *Alnus japonica* is located on moorland (Fig. 1). On the contrary, *Quercus* and *Pinus* are located on every slopes. In addition, Omori *et al.* (1980) observed the similar relationships at the subalpine zone in Chubu district, *i.e. Betula* forest situating on the mountain side, where the surface materials are relatively unstable. *Abies* and *Picea* are located on the Crest slope or terrace surface. Therefore we tentatively applied this relationship onto pollen grains and sediments of bog deposits.

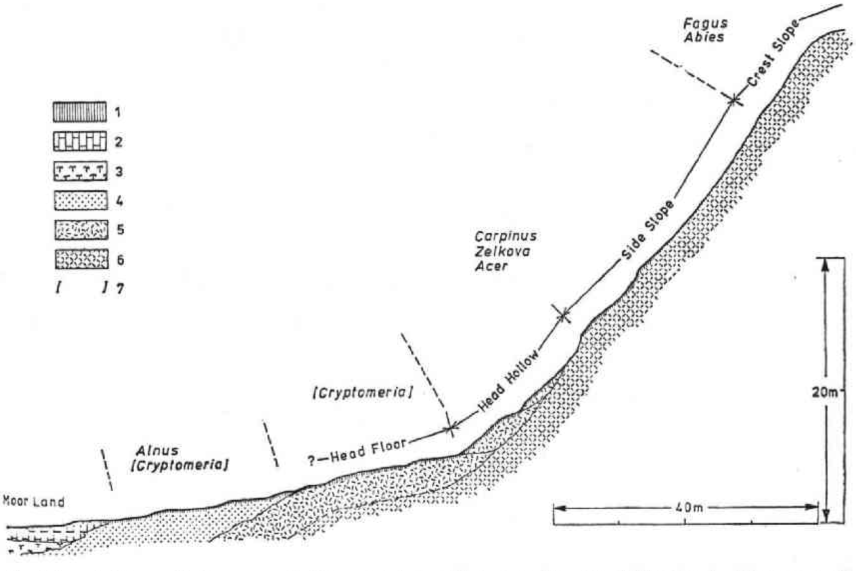

Fig. 1 Correlation of the vegetation and landform units in hilly land (Slope profile: Moniwa-Takada)
1; humus, 2; organic material, 3; peat, 4; sandy loam, 5; colluvial slope deposit, 6; basements, 7; plantation

Deposits from the hillslopes are often interbedded with peat layer in the depression. The peat and loamy layers provide adequate materials for pollen analysis and radiocarbon dating, and enable to observe the fluctuation of the slope deposits, which suggests the chronology of environmental changes. The increase and decrease of pollen grains lead us not only to the change of climate but also to the change of plant community behavior, moreover to the change of micro-landform condition. In this way, hillslope development in the past will be restored.

2 Area and method

2.1. Study areas

Study areas are shown in Fig. 2. Both Moniwa-Takada moor and Nenoshiroishi moor are located at typical valley head areas about 200–300 m a.s.l. and they consist of Neogene sedimentary rocks such as tuffaceous sandstone, tuffaceous siltstone, shale and pumiceous tuff. The moors were naturally dammed by landslide blocks about 20,000 to 30,000 yr BP (Miyagi 1981). Isupo moor, about 400 m a.s.l. was dammed by a huge landslide before 37,000 yr BP (Miyagi 1981). It is

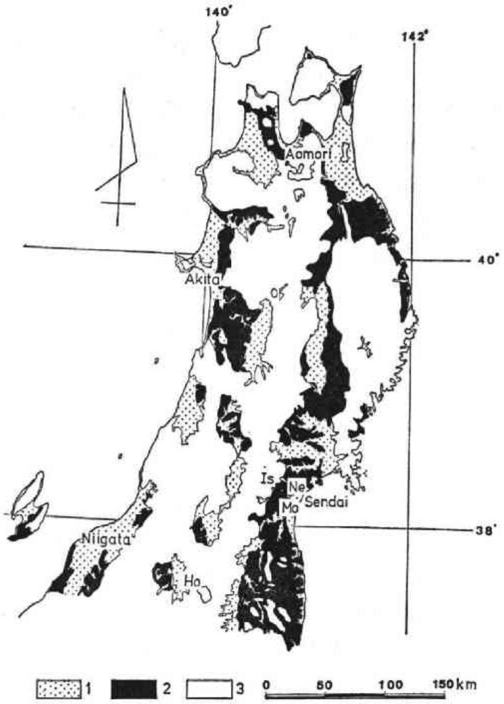

Fig. 2 Location map of study areas: 1; plain and upland, 2; hilly land, 3: mountain, **Mo**; Moniwa-Takada, Ne; Nenoshiroishi, Is; Isuponuma, Ho; Hoshojiri.

situated between main sliding scarp and landslide block. Hoshojiri bog was dammed by volcanic mudflow from Mt. Bandai, Fukushima Prefecture. It is situated about 500 m a.s.l.

2.2. Method

Fossil pollen samples were collected from the deepest point of each moor by Hiler type pollen sampler, and analysed by the KOH-Acetolysis-$ZnCl_2$ method. More than 200 arboreal pollen were examined for each sample and percentage frequency was calculated for each species.

Radiocarbon dating samples were collected from the same point with hand boring tool (called Nakata type borer) or Hiler type pollen sampler.

Geological structures were clarified from many borings along the long axis of the moor.

3 Analysis

3.1. Moniwa-Takada moor

Fig. 3 is a geologic section along the valley of Moniwa-Takada moor. Sandy loam with angular gravel of sandy tuff was deposited from –7 m upto about –5.5 m (8,800 yr BP). Lower peat layer was overlying till about –4.2 m (7,800 yr BP). There above till –2.5 m (2,500 yr BP) inorganic clay and silt horizon or organic clay horizon was extended, especially showing the period between 6,000 and 5,000 yr BP Pure peat was covering till –0.8 m (1,000 yr BP). Then, upto the present moor floor, not peaty organic material has been developed.

Therefore, the deposit in this geologic section is divided into three inorganic horizons and two peat layers.

From the surface to about 3.8 m below the pollen and spore are determined as follows: *Pinus, Cryptomeria, Fagus, Zelkova, Carpinus, Betula, Quercus, Juglans, Pterocarya, Alnus, Castanea, Corylus, Acer, Aesculs, Tsuga, Celtis, Salix, Abies,* Ericaceae, *Rhus, Ilex, Vibrunum,* Compositae, *Chenepodium, Artemisia, Percicarya,* Cyperaceae, Gramineae, *Typha,* Liliaceae, *Thalictrum,* Umbelliferae, *Sanguisorba* and Fern spore. The sequences of main pollen and spore are shown in Fig. 4.

The diagram shows a general tendency similar to other Holocene palynological data from deciduous forest in northeast Japan, *i.e. Pinus* and *Cryptomeria* are abundant in the surface zone and suddenly decrease downward. *Fagus* is the most abundant at the period between 7,900 and 1,000 yr BP. *Quercus* increases with the depth increasing. From these data, the following three stages are recognized.

M–I *Quercus – Fagus* stage (–380∼–150 cm)
M–II *Fagus – Quercus* stage (–140∼–40 cm)
M–III *Pinus – Abies – Cryptomeria* stage (–30∼0 cm)

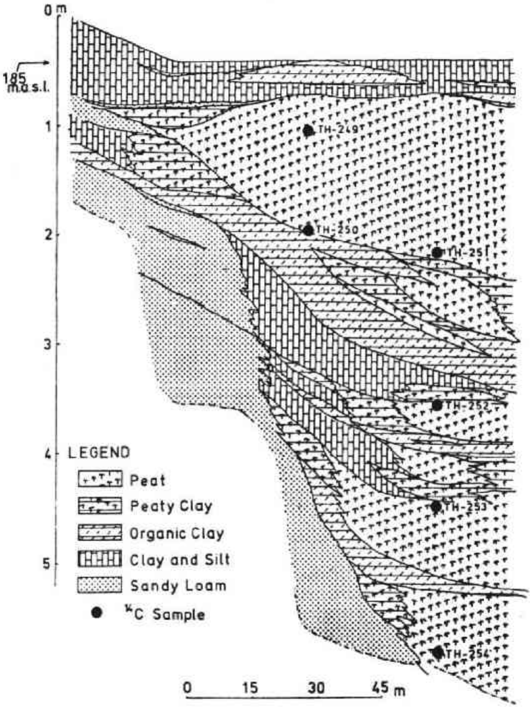

Fig. 3 Geological section of Moniwa-Takada moor

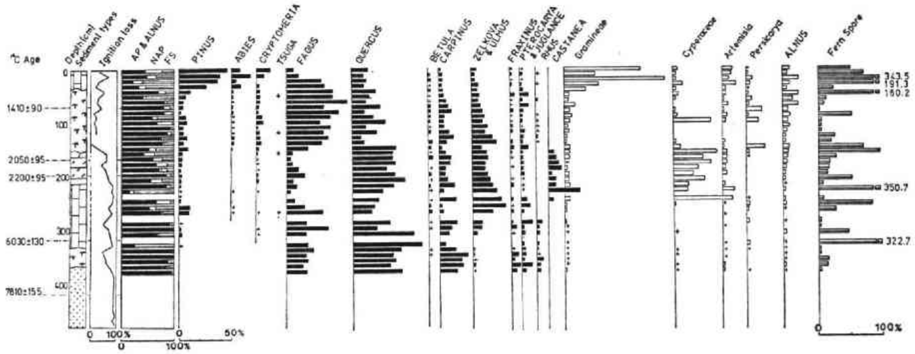

Fig. 4 The pollen diagram from the Moniwa-Takada moor

In the middle inorganic horizon, the trees favourite on Side slope such as *Zelkova, Ulmus, Carpinus* and *Castanea,* and Cyperaceae are rich but *Fagus* favourite on Crest slope is poor. Fern spore sharply increases just below and above this horizon. *Fagus* is rich in the pure peat layer.

Table 1 The data for radiocarbon dating

No.	Locality, Geomorphology	Code No.	Below surface (m)	Radiocarbon age yr BP (1950)	Material
15	Moniwa-takada Moorland	TH–249	0. 7	1, 410± 90	Peat
16		TH–250	1. 7	2, 050± 95	Peat
17		TH–251	2. 0	2, 200± 95	Peat
18		TH–252	3. 2	6, 030±130	Peat
19		TH–253	4. 2	7, 810±155	Peat
20		TH–254	5. 4	8, 860±175	Peat clay
23	Moniwa-nashino Lacustrine terrace	TH–364	3. 5	8, 120±170	Organic clay
4	Nenoshiroishi. Moorland	TH–291	1. 1	920±100	Peat
5		TH–292	2. 0	2, 420±105	Peat
6		TH–293	3. 0	4, 290±130	Peat
7		TH–294	4. 0	6, 070±150	Wood
8		TH–295	5. 1	7, 600±160	Peat
9		TH–296	6. 1	7, 160±155	Peat & Wood
10		TH–297	7. 0	6, 330±145	Wood
1	Hosyojiri Moorland	N–3068	0. 65	3, 250± 95	Clayey peat
2		TH–462	1. 2	4, 810±140	Peat
3		TH–463	1. 75	9, 680±240	Peat
4		N–3067	2. 05	11, 700±160	Peat
5		N–2893	2. 8	14, 500±140	Peat
6		TH–427	3. 5	16. 470±450	Peat
11	Isupo-numa Moorland	TH–368	0. 7	2, 730±110	Peat
12		TH–461	1. 25	15, 140±430	Peat
13		TH–319	2. 9	18, 110±490	Peat

3.2. Nenoshiroishi

Fig. 5 is a geologic section of Nenoshiroishi moor deposit. Three inorganic horizons are also identified. The lower horizon is below about –6 m, perhaps deposited till about 9,000 yr BP. The middle horizon between –4 and –2 m, developed between 6,000 and 2,500 yr BP. It extends widely at –3.8 m level, corresponding the period between 6,000 and 5,000 yr BP. The upper horizon is –0.7 m onward. Peat layers occupy other horizons.

The pollen and spore from the surface to the depth of 5.7 m are determined as follows: *Pinus*, *Abies*, *Tsuga*, *Cryptomeria*, *Podocarpus*, *Fagus*, *Quercus*, *Cyclobalanopsis*, *Zelkova*, *Ulmus*, *Juglans*, *Pterocarya*, *Castanea*, *Carpinus*, *Corylus*, *Alnus*, *Betula*, *Fraxinus*, *Ilex*, *Acer*, *Sorbus*, *Salix*, *Tilia*, *Rhus*, Ericaceae, *Aesculus*, *Miryca* (?), *Celtis*, *Iillicum*, *Vibrunum*, *Nymphaea*, *Polygonum*, *Sanguisorba*, Umbelliferae, *Typha*, *Percicaria*, Compositae, Gramineae, *Artemisia*, Cyperaceae, *Harolagis*, *Trapa*, *Impatiens*, *Humalus*, *Nuphar*, *Hydrilla*, *Thalictram* and Fern spore. The sequences of main pollen and spore are given in Fig. 6.

This diagram also shows a general tendency similar to other data. Based on these data, the following five stages are recognized.

N–I *Fagus – Quercus – Carpinus* stage (–570∼–470 cm)
N–II *Fagus – Quercus – Zelkova* stage (–460∼–280 cm)
N–III *Quercus – Fagus – Zelkova* stage (–270∼–150 cm)
N–IV *Fagus – Quercus – Alnus* stage (–140∼–50 cm)

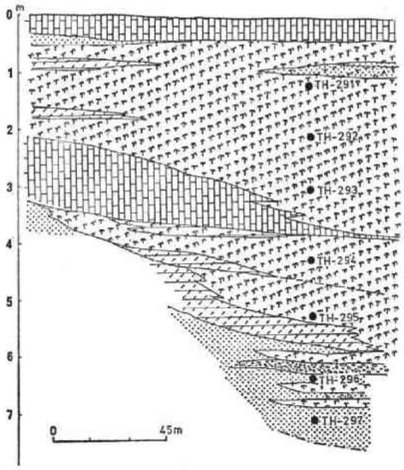

Fig. 5 Geological section of Nenoshiroishi moor

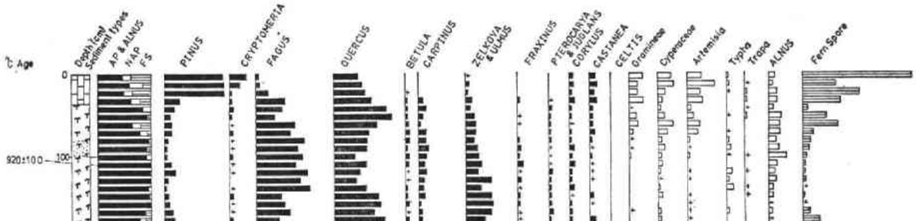

Fig. 6 The pollen diagram from the Nenoshiorishi moor

N–V *Pinus – Quercus – Cryptomeria* stage (–40∼–0 cm)

N–I, II and III are correlated with R II stage (Nakamura 1952), N–IV is correlated with R IIIa, and N-V is correlated with R IIIb (Nakamura 1952, Tsukada 1967). The boundary of the N-III and N-IV is dated about 2,000 yr BP. In the upper inorganic horizon, *Pinus*, *Cryptomeria*, non arboreal pollen and Fern spore increase immediately after about 1,000 yr BP. In the middle inorganic horizon, all *Zelkova* and *Ulmus*, *Carpinus*, *Fraxinus* increase at once, while, *Fagus* and *Quercus* decrease. The total of *Zelkova* and *Ulmus*, *Carpinus*, and *Fraxinus* pollen amounts to 60% at 6,000 yr BP.

These tendencies are similar to those of Moniwa-Takada moor. And in the Nenoshiroishi horizon, such plants growing on flooded area as *Trapa*, *Typha*, *Hydrilla* and *Nuphar* are absent in the middle inorganic horizon.

3.3. Hoshojiri

Fig. 7 is a geologic section of Hoshojiri bog, whose deposit is divided into several horizons. Basal sandy loam is deposited at –6.1 m. Lower organic clay or peaty clay were accumulated upto –4.1 m (21,000 yr BP), then, clayey peat layer was accumulated till about 13,000 yr BP. Middle organic clay or peaty clay extended between 13,000 yr BP and 9,000 yr BP. Fresh pure peat layer was accumulated upto 6,000 yr BP. Upper sandy loam layer was developed till about 3,000 yr BP. Another pure peat layer was accumulated till bout 1,000 yr BP. Surface muck has been developed after 1,000 yr BP.

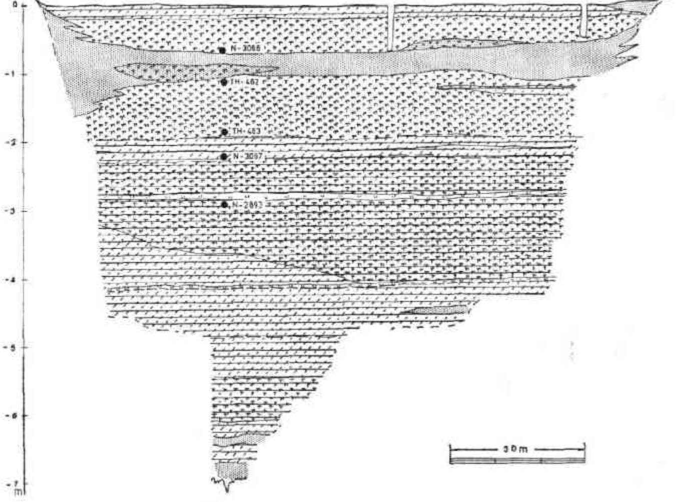

Fig. 7 Geological section of Hoshojiri bog

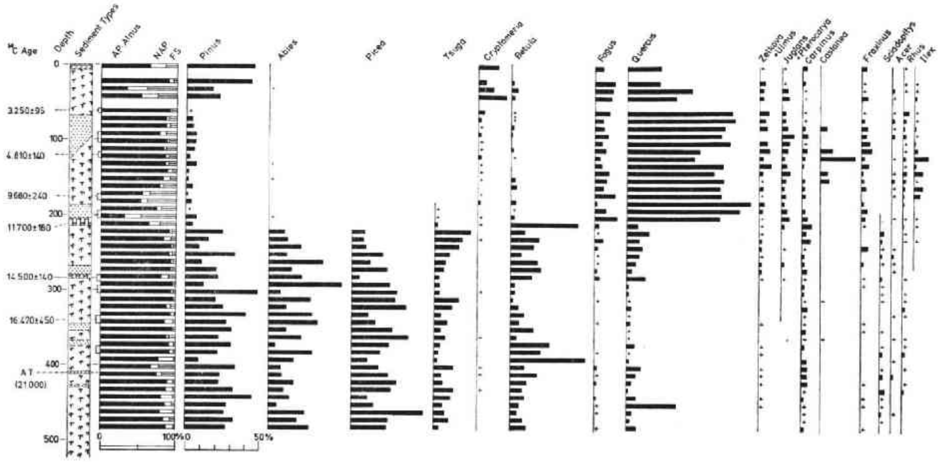

Fig. 8 The arboreal pollen diagram from the Hoshojiri bog

Besides, a thin volcanic ash layer is imbedded about –4 m, correlated to Aira-Tanazawa (AT) pumice about 21,000 yr BP (analysed by Dr. Machida and Dr. Arai). And upper sandy loam horizon includes the Numazawanuma pumice about 5,000 yr BP.

The pollen and spore determined from the surface to the depth of 4.9 m are as follows: *Pinus, Picea, Abies, Cryptomeria, Sciadopitys, Tsuga, Fagus, Quercus, Betula, Carpinus, Corylus, Acer, Rhus, Ulmus, Zelkova, Tilia, Aesculs, Fraxinus, Hamaelis,* Ericaceae, *Vitis, Pterocarya, Juglans, Salix, Ilex, Castanea, Alnus,* Gramineae, Cyperaceae, *Artemisia,* Compositae, Umbelliferae, *Percicarya, Thalictrum,* Chenopodiaceae, Liliaceae, *Haloragis, Galium, Plantago, Typha, Nymphaea,* Labiatae, *Impatiens, Fagopyrum* and Fern spore. The sequences of main arboneal pollen are given in Fig. 8.

Diagram shows the clear boundary of the last glacial age and the post glacial age, *i.e.* the evidence of subalpine evergreen coniferous forest such as *Picea, Tsuga, Abies, Pinus,* and *Betula* disappear together at about –2.1 m (12,000 yr BP), and deciduous trees such as *Quercus* and *Fagus* appear immediately, but geologic unconformity is not recognized. From these data, following three stages are recognized (Kawamura 1979).

H–I *Pinus – Abies – Picea – Tsuga – Betula* stage (–490∼–210 cm)

H–II *Quercus – Fagus* stage (–200∼–60 cm)

H–III *Pinus – Cryptomeria – Quercus – Fagus* stage (–40∼0 cm)

H–I, II and III are correlated with L, RII and RIII respectively. The boundary of the H–I and H–II is at about 12,000 yr BP.

Between 22,000 and 18,000 yr BP, *Betula* is richest, on the contrary *Picea, Abies* and *Pinus* are poor. Between 18,000 and 13,000 yr BP, the trees such as *Picea* and *Abies* kept dominance on stable slope in subalpine zone.

The horizon of middle organic clay at the period between 13,000 and 9,000 yr BP is to be attentioned, which is correlated to the sandy loam layer in the Moniwa-Takada and Nenoshiroishi moor deposit. These horizons are rich in evidences of unstable condition of surrounding slopes. In the lower half of this horizon *Betula* and *Tsuga* pollen increase, and on the contrary *Picea* and *Abies* decrease. *Carpinus* also increases in the upper half of this horizon.

Zelkova, Ulmus, Fraxinus and *Castanea* increase and *Quercus, Fagus* decrease between about 6,000 and 3,000 yr BP.

3.4. Isuponuma

The deposit of Isuponuma moor largely contains coarse material and its geologic section is shown in Fig. 9. It seems to have been supplied from the large sliding

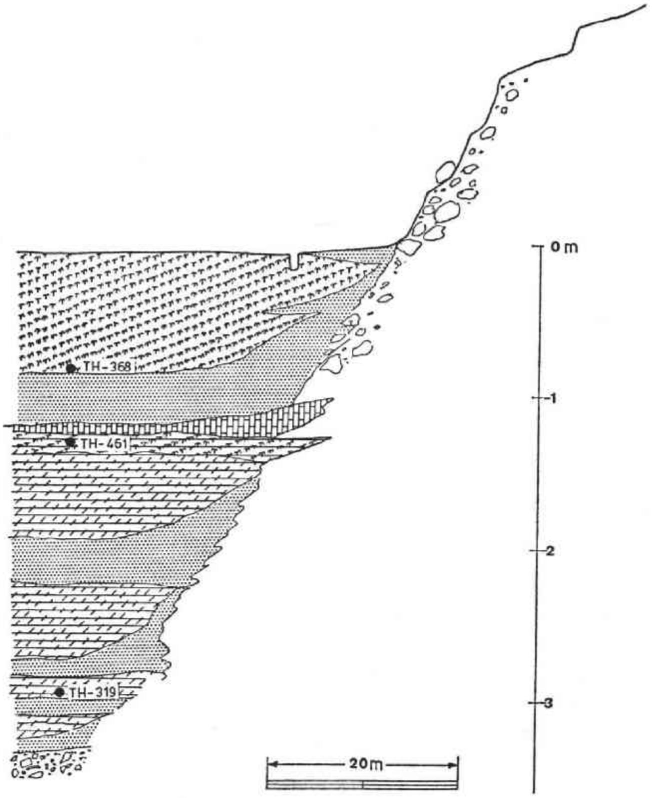

Fig. 9 Geological section of Isuponuma moor

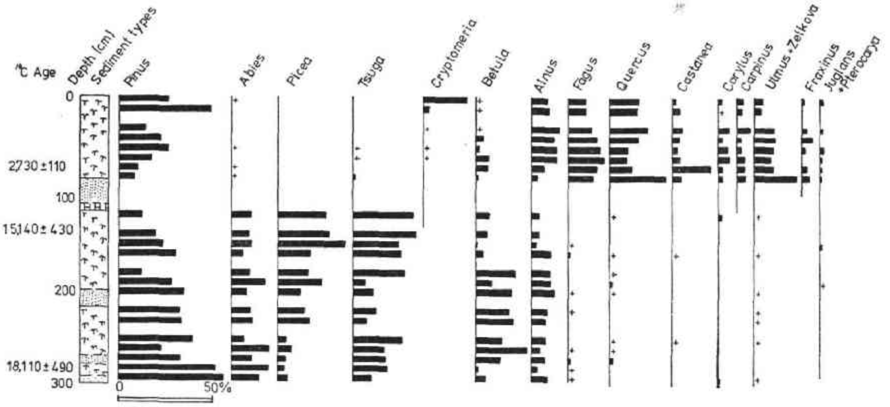

Fig. 10 The arboreal pollen diagram from the Isuponuma moor

scarp in the north side. The section is similar fundamentarily to Hoshojiri bog deposit.

The pollen and spore from the surface to the depth of 3 m are identified as follows: *Pinus, Abies, Picea, Tsuga, Cryptomeria, Betula, Alnus, Fagus, Quercus, Castanea, Corylus, Carpinus, Ulmus, Zelkova, Fraxinus, Juglans, Pterocarya,* Ericaceae, Gramineae, *Artemisia,* Compositae, Cyperaceae, *Thalictrum, Haloragis, Persicaria* and Fern spore. The diagram of main pollen and spore is given in Fig. 10, from which following four stages are recognized.

I–I *Pinus – Betula – Abies* stage (–290∼–170 cm)
I–II Tsuga – Picea – Pinus stage (–160∼–120 cm)
I–III Quercus – Fagus stage (+80∼–30 cm)
I–IV Pinus – Cryptomeria stage (–20∼–0 cm)

I–I, II, III and IV stages are correlated to L,L,RII and RIII respectively.

There are no particular correspondence between pollen grain ratio and deposit facies. The upper sandy loam horizon (–120∼–80 cm) has very coarse material, and the sampled pollen is not dated between 12,000 and 3,000 yr BP, *Zelkova* and *Ulmus* are increasing just above the upper sandy loam.

4 Conclusion

The facies of geologic sections are good records of local denudation processes on hillslope around the small depression. On the other hand, the palynological data reflect environmental change of wider area. Many arboreal pollens are scattering to the area of several square kilometer from the original forest, even small in quantity (1∼2% or several grains). Such pollens as *Fagus, Abies, Tsuga* and *Betula* are carried by wind for a long distance (about 40～60 km) (Hibino 1968, 1969, Hibino and Yasuda 1973).

Care must be taken that the close relationship between micro-landform units and vegetations well preserved in the relationship between the facies of bog deposits and the fluctuation of pollen grains. The interrelation among total pollen percentage of the trees stand on unstable slope and inorganic horizons with hillslope instability is summarized in Fig. 11. The unstable slopes such as Side slope, Head hollow and Head floor are mostly covered with *Zelkova serrata*, *Carpinus tschonoskii*, *C. laxiflore*, *Fraxinus*, and *Ulmus davidiana* in Holocene, and *Betula* and *Tsuga* in glacial age. These pollens are well included in inorganic horizons of bog deposit.

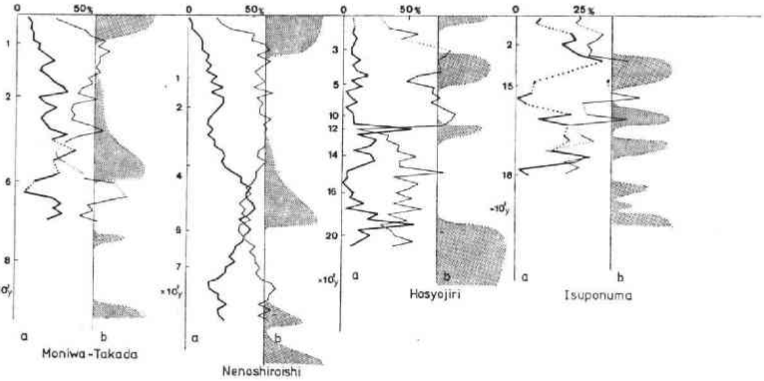

Fig. 11 Correlation of the pollen and inorganic horizons. a; pollen, — is total pollen of *Zelkova*, *Ulmus*, *Carpinus*, *Fraxinus*, *Acer* and *Betula*, — is total of *Fagus*, *Quercus*, *Abies* and *Picea*. b; inorganic horizon

On the stable slope such as Crest slope, *Fagus crenata*, *F. japonica*, *Abies*, *Picea* and partly *Pinus* stand, and these pollens are dominant in the peat layer.

Based on these phenomena, four periods of hillslope instability are identified, *i.e.* before 20,000 yr BP, 12,000 to 9,000 yr BP, 6,000 to 2,500 yr BP, especially unstable 6,000 to 5,000 yr BP and after 1,000 yr BP. The unstable period 6,000 to 5,000 yr BP was contemporal with the Hypsithermal epoch. Inorganic tendency of after 1,000 yr BP is a nationwide phenomenon in Japan (Sakaguchi 1979). The deposit of Holocene-Pleistocene boundary is very coarse, and facies change is extreme, and the period is unstable one.

The hillslope development under changing environment in humid temperate area are recognized as follows. The hillslope instability accompanies with phase to phase of climatic change, not only cold or warm conditions.

Hillslope denudation during Holocene, mainly consists of soil creep on Crest slope mostly in the stable period, and surface failure of slump type on Side slope and Head hollow mostly in the unstable period.

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References (* in Japanese ** in Japanese with English abstract)

Hack, J.T. and J.C. Goodlett (1960): Geomorphology and forest ecology of a mountain region in the central Appalachians. *U.S. Geol. Surv. Prof. Pap.*, **347** 1–66

Hibino, K. (1968): Fossil and Air-borne Pollen in relation to the Living Vegetation in Mt. Hakkoda. *Ecol. Rev.*, **17** 103–108

——— (1969): Relation between Air-borne Pollen and the Living Vegetation in Mt. Hakkoda. *ibid.*, **17** 189–195

——— **and Y. Yasuda** (1973): Relation between Air-borne Pollen and the Living Vegetation in Miyagi Prefecture.** *Ann. Tohoku Geogr. Assoc.*, **25** 224–230

Higaki, D. (1980): Tephrochronological Study of Slope Deposits in the Northwestern Kitakami Mountains. *Sci. Repts. Tohoku Univ. 7th Ser. (Geogr.)*, **30** 147–156

Kaizuka, S. (1970): Climatic Geomorphological Region in Würm Glacial age of Japanese Island.** *Geogr. Rev. of Japan*, **43** 116–117

Kawamura, T. (1979): Palynological studies of deposits in Tohoku district – Special reference to the distribution of *Cryptomeria japonica* –.** *The Quaternary Research*, **18** 79–88

Makita, H., T. Miyagi, O. Miura, and T. Kikuchi (1979): A Study of an Alder Forest and an Elm Forest with Special Reference to their Geomorphological Conditions in a Small Tributary Basin. Vegitation und Landschaft Japans. Festsch. für Prof. Dr. Drs. h.c.R. Tüxen zum 80. Geburtstag Bull. Yokohama Phytosoc. Soc. Japan **16** 237–244

Miura, O. and T. Kikuchi (1978): Preliminary Investigation on a Vegetation and Micro-Landforms at a Valley Head in the Hills.* *Plant Ecology to the Memory of Dr. K. Yoshioka*, 466–477

Miyagi, T. (1979): Process of Valley Development by Slope Failures in Hilly Lands around Sendai, Northeast Japan.** *Geogr. Rev. of Japan*, **52** 219–232

——— (1981): Geomorphological Conditions of Sendai City and its Environs. Significance of the Fossil Landslide in Hilly Land.** *Bull. of North Japan Cultural Inst.*, **12** 21–29

———, **K. Hibino and T. Kawamura** (1979): Processes of Hillslope denudation and environmental changes during the Holocene around Sendai, Northeast Japan.** *The Quaternary Research*, **18** 143–154

Moriya, I. (1972): Landform classification and Geomorphological development of mountain slope by landslide topography.* *Abstracts of the Assoc. Japanese Geogr.*, **2** 168–169

Nakagami, K. (1979): *Palynological analysis and radiocarbon dating of bog deposits in southern Tohoku district (M.S.)**. Graduation Thesis of Tohoku Univ., 1–45

Nakamura, J. (1952): A comparative study of Japanese pollen records. *Res. Rep. Kochi Univ.*, **1** 1–20

Omori, H., H. Sohma and S. Takiguchi, (1980): Relationship between vegetation and slope stability in the northern Japanese Alpe, Central Honshu. *Japan. 24th Inter. Geogr. Congr. Main Ses. Abstracts*, **1** 270–271

Omoto, K. (1978): Tohoku University Radiocarbon Measurements VI. *Sci. Repts. Tohoku Univ. 7th Ser. (Geogr.)* **28** 101–116

Riezebos, P.A. and R.T. Slotboom (1974): Palynology in the Study of Present-day Hillslope Development. *Geologie en Mijnbouw,* **53** 436–448

Sakaguchi, Y. (1979): Distribution and Genesis Japanese Peatlands. *Bul. Dept. Geogr. Univ. Tokyo,* **11** 17–42

Suzuki, H. (1962): Southern boundary of lowland periglaciation and climatic boundary of the last Glacial age.** *Geogr. Rev. of Japan,* **35** 67–76

Tamura, T. (1969): A Series of micro-landform units composing valley-heads in the hills near Sendai. *Sci. Repts. Tohoku Univ.* **7*th*** *Ser. (Geogr.),* **19** 111–127

——— (1974): Recent Geomorphology, **5**. Landform and soil.* *Soil and substructure,* **22** **5** 89–94

——— **and O. Miura** (1968): The period of Slope-Instability Observed in tephra in a Coastal Area from Hachinohe City, Northeastern Japan.** *Ann. Tohoku Geogr. Assoc.,* **20** 69–73

———, ——— (1971): Slope deposits in the Northern Margin of Kitakami Massif, Northeast Japan.** *The Quaternary Research,* **10** 21–29

Tsukada, M. (1967): The Last 12,000 Years: A Vegetation History of Japan I.** *Bot. Mag. Tokyo,* **80** 323–336