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Pollen Analytical Study of Holocene Earth Surface Environment Change in Sakunami, Northeastern Japan
— With Special Reference to Ulmus/Zelkova as an Indicator of Hillslope Instability —

Ji-Hoon PARK*

Abstract A closed depression in the Sakunami Landslide, about 430 m a.s.l., west of Sendai, is filled by peaty deposits about 5 m deep, which intercalate several inorganic layers. Pollen analysis of peaty deposits distinguished the following three pollen zones: S-I zone: Quercus—Fagus forest (R I), S-II zone: Quercus—Fagus—Ulmus/Zelkova forest (R II), S-III zone: Fagus—Quercus forest (R II), which corresponds to the present lower montane forest. The peat layer at the boundary of S-I and S-II, 430 cm below the surface (S5) showed the radiocarbon date of 8,300±50 y.B.P. (TH-1958). The peak of Ulmus/Zelkova occurred in inorganic layers, i.e., 320 cm and 230 cm below the surface (S-5), which were the records of debris inflow from surrounding slopes. Observation of present vegetation shows that Ulmus/Zelkova forests tend to be distributed on disturbed hillslope. Moreover, the increase of Ulmus/Zelkova together with Betula in previously reported pollen diagram corresponds to climatic and vegetational transition phases, i.e., those of the Early Holocene and three warming phases of the middle Last Glacial. The facts suggest that the peak of Ulmus/Zelkova is a result of hillslope instability, which was induced frequently in the periods of climatic transition. Thus two periods of hillslope instability were identified since the early Holocene in the depression.

Key words: pollen analysis, Holocene, hillslope instability, Ulmus/Zelkova

1. Introduction

If instability of hillslope around an isolated depression was induced by change in climate and others factors, it is expected to be recorded with the change in both pollen assemblage andolithofacies of the depression fills. Based on the idea, Miyagi et al. (1979, 1981), and Nakayama and Miyagi (1984) correlated the pollen sequence taken from depressions in Northeastern Japan and discussed the relationship between hillslope instability and environmental change. The method, however, requires fur-
ther examination of temporal and spatial resolution of depression deposits in the analysis of hillslope denudation processes. Moreover, it is necessary to accumulate case studies which investigate the stands of plant communities from the viewpoint of earth surface processes. In this context, it should be remarked that *Zelkova serrata* forest tends to occur on disturbed hillslopes such as slide slopes and head hollows and *Ulmus davidiana* covers debris deposited in head floors (e.g., Miura and Kikuchi 1978; Makita et al., 1979).

A few pollen analytical studies, *i.e.*, Nakayama and Miyagi (1984) and Park and Hibino (1999), reported that *Ulmus/Zelkova* increases together with *Betula* in the periods of climatic and vegetational transition, such as the Early Holocene and the three warming phases of the middle Last Glacial. In addition, it was revealed in several moors in Northeastern Japan that the transitional periods show similar pattern in pollen successions but their ages are different in different localities even in nearby
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areas (e.g., Kawamura, 1977; Miyagi et al., 1981; Tsuji et al., 1983; Nakayama and Miyagi, 1984). The facts lead to the consideration that vegetation change in the transitional period is related to not only climatic aspect but also abrupt change in earth surface condition (Park and Hibino, 1999).

This paper analyzes the pollen sequence since the early Holocene, and discusses the relation between Ulmus/Zelkova and periods of hillslope instability in an isolated depression situated in an old landslide about 430 m a.s.l. which is close to the Sa-kunami-Yashikidaira Fault, west of Sendai, Northeastern Japan (Fig. 1). The depression is presently occupied by a moor covered by Phragmites communis. The hillslopes around the moor are dominated by plantations of conifers such as Cryptomeria japonica.

Fossil pollen samples were collected from the deepest point of the moor using a Hiller type sampler and treated by the KOH-Acetolysis-ZnCl₂ method. More than 250 arboreal pollen (AP) was examined for each sample as the basal number to obtain percentage. The pollen frequencies were expressed as percentages of AP except Alnus. Radiocarbon dating by the metanol liquid scintillation method was applied to the peat sample collected from 4.3 m below the surface (S-5). A geological section was clarified based on the results of many hand borings along the long axis of the moor (Fig. 2).
2. Geological section of Sakunami depression deposit

Fig. 3 shows a geological section of Sakunami depression. Several inorganic parts are distinguished in the deposits which fill the depression. They seem to have been mainly supplied from valleys on the northwestern side of the depression.

The basal inorganic part (I) is identified below about $-4.6 \text{ m}$ at S-5. The part consists of greenish gray clay layers with angular gravel and a gray clay/silt layer. The thickness of the part I is more than $80 \text{ cm}$ at S-5. The lower inorganic part (II) is recognized between $-4.2$ and $-3.7 \text{ m}$ at S5. The part consists of gray clay layers with angular gravel. Four thin inorganic layers are intercalated in peaty deposits. The horizon between part I and part II corresponds to $8,300 \pm 50 \text{ y. B.P.}$. The middle inorganic part (III) is recognized between $-2.5$ and $-1.5 \text{ m}$ at S3. The part consists

![Geological section of Sakunami depression](image-url)
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of gray clay layers with angular gravel. Its thickness is about 100 cm at S3. The upper inorganic part (IV) is recognized between −1.4 and −1.0 m at SK3. The part consists of a gray clay layer with angular gravel and a gray clay or silt layer. Its thickness is about 40 cm at S3.

In consideration of rather popular occurrence of inorganic layers in the period after 1,000 y.B.P. in Japan (Sakaguchi, 1979), the part IV seems to have been deposited by 1,000 y.B.P., though there is no radiocarbon date. The geologic section of Sakunami depression is almost similar to those of Moniwa-Takada moor and Nenoshiraoisi moor deposits reported by Miyagi et al. (1981).

3. The pollen zones

The pollen determined from the samples amounted to 1 family 22 genera of tree pollen, 8 family 14 genera of non-tree pollen, and spore. The sequence of main pollen, which is given in the pollen diagram (Fig. 4), shows the following three pollen zones.

S-I  Quercus—Fagus zone (from -560 to -440 cm)
S-II  Quercus—Fagus—Ulmus/Zelkova zone (from -380 to -120 cm)
S-III  Fagus—Quercus zone (from -110 to -50 cm)

S-I zone is represented by the predominance of deciduous trees such as Quercus and Fagus. Very few or no conifers such as Pinus and Abies occur in the zone. Ecological consideration indicates that Quercus in this zone was originated from Q. crispula and Q. serrata. Fagus is considered from the ecological feature of plant to have been probably originated from F. crenata and F. japonica. S-I zone corresponds to the lower montane forest. S-I zone can be correlated with R I advocated by Nakamura (1952).

S-II zone is represented by the predominance of Quercus and Fagus like S-I zone. Other deciduous trees such as Ulmus/Zelkova, Castaneae etc., also show the increase in comparison with S-I zone. Especially it is worthy of attention that Ulmus/Zelkova reaches the maximum occurrence in this zone. The occurrence pattern of Ulmus/Zelkova at Sakunami depression is similar to those of Moniwa-Takada moor and Nenoshiraoisi moor (Miyagi et al., 1981) (Fig 5). Ulmus and Zelkova are considered from their ecological feature to have been probably originated from U. davidiana, U. tacentiata and Z. serrata, respectively. Peat obtained from the boundary between S-I and S-II has been dated as 8,300±50 y.B.P. (TH-1958).

S-III zone is characterized by the gradual increase of Fagus and decrease of Quercus. Ulmus/Zelkova which is dominant in the S-II zone decreases in the S-III zone.

S-II and S-III zones correspond to the lower montane forest (the cool temperate deciduous broad-leaved forest). The zone can be correlated with R II, and probably
Fig. 4. The pollen diagram from the Sakumami depression. Symbols are the same as those of Fig. 3.
Fig. 5  Correlation of inorganic layers and the occurrence of Ulmus/Zelkova pollen Modified from Miyagi et al. (1981). Symbols are the same as those of Fig. 3.
corresponds to the Quercus—Fagus stage in Moniwa-Takada moor, the Fagus—Quercus—Carpinus stage, Fagus—Quercus—Zelkova stage and the Quercus—Fagus—Zelkova stage in Nenoshiroishi moor, and the Quercus—Fagus stage in Isuponuma moor (Miyagi et al., 1981).

4. Periods of hillslope instability

The lithofacies of geologic sections are good records of local denudation process on hillslope in the watershed of the depression. It is observed in present mountains and hills that Zelkova serrata forest tends to occur on the disturbed hillslopes such as slide slopes and head hollows and Ulmus davidiana forest covers debris deposited on the head floors (e.g., Miura and Kikuchi, 1978; Makita et al., 1979). There is the close relation between the fluctuation of Ulmus/Zelkova pollen and the general trend of hillslope instability in the changing balance of temperature and precipitation (e.g., Miyagi et al., 1981).

Fig. 5 summarizes previous reports on the relation between Ulmus/Zelkova and inorganic layers. Small peaks of Ulmus/Zelkova in pollen diagrams well correspond with inorganic layers within depression deposits in Moniwa Takada moor, Nenoshiroishi moor and Isuponuma moor (Miyagi et al., 1981). Sakunami depression shows similar trend of relation between Ulmus/Zelkova and inorganic layers to the above three moors.

The following four inorganic parts are identified, in the geological section, i.e., below −4.6 m (S-5), −4.2 to −3.7 m (S-5), −2.5 to −1.5 m (S-3), and −1.4 to −1.0 m (S-3) (Fig. 3). If the fluctuation of Ulmus/Zelkova can be interpreted as the unstable periods of hillslope, two unstable period occurred around Sakunami depression, i.e., 320 cm and 230 cm below the surface (Fig. 4).

It is noticeable that the close relationship between disturbed hillslopes and Ulmus/Zelkova is well preserved in the relationships between the lithofacies of depression deposits and pollen records. It can be induced that peak of Ulmus/Zelkova is a result of hillslope disturbance due to the frequent occurrence of regolith slides under the similar climatic environment as the present.

The information of present vegetation indicate that the increase of Ulmus/Zelkova can be utilized as a signal of earth surface disturbance in the past (Park and Hibino, 1999).

5. Concluding remarks

The following pollen succession has been recognized in a closed depression in a big landslide zone at Sakunami, Northeastern Japan;
S-I zone: *Quercus—Fagus* forest, R I
S-II zone: *Quercus—Fagus—Ulmus/Zelkova* forest, R II
S-III zone: *Fagus—Quercus* forest, R II

The pollen diagram shows that the peaks of *Ulmus/Zelkova* occur in inorganic layers as 320 cm and 230 cm below the surface. Comparative investigation of previous pollen records and the present one leads to the interpretation that the peak of *Ulmus/Zelkova* is a result of increased disturbance of hillslopes, i.e., frequent occurrence of regolith slides probably under similar climatic environment to present one. If the fluctuation of *Ulmus/Zelkova* is utilized as an indicator of hillslope instability, such periods occurred twice since the early Holocene around Sakunami.

Because frequent occurrence of regolith slides is expected to be recorded on hillslope microforms and regolith profiles, micro-landform characteristics should be more carefully investigated with particular attention to the distribution of *Ulmus/Zelkova* forest in the watershed of the depression.

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