Suppl. Geogr. Fis. Dinam. Quat.
VI (2003), 85-89, 6 figg.

AKIHIKO SASAKI (*)

HOLOCENE VEGETATION CHANGES INFERRED FROM SOIL STRATIGRAPHY ON MT. SUMON-DAKE, CENTRAL JAPAN

ABSTRACT: SASAKI A., *Holocene vegetation changes inferred from soil stratigraphy on Mt. Sumon-dake, Central Japan.* (IT ISSN 1724-4757, 2003).

Geo-historical surveys of slopes and soil stratigraphy shows the changes in vegetation on the present-day upper montane zone of Mt. Sumon-dake (1,538 m a.s.l.; 37°23'N, 139°08'E) since the Late Glacial when the slopes were covered poorly vegetation. The snowpatch meadows widely covered the crest gentle slopes between the summit and 1,250 m in altitude in the early Holocene, indicated by initiation of the herbaceous peaty soil layer. Although the vegetation zones shifted upward in response to the warming after the Last Glacial, the upper limit of the continuous montane vegetation area represented by *Fagus crenata* trees remained at 1,200-1,300 m in altitude, 100-250 m lower than present, in the early Holocene. The widely distributed snowpatch meadows continued to exist on the slopes above 1,200-1,300 m in altitude during the early to middle Holocene instead of *F. crenata* forest. The changes in vegetation were strongly controlled by heavy snow accumulation since the Late Glacial.

KEY WORDS: Japanese snowy mountains, Montane zone, Peaty soil, Tephrochronology, Holocene.

INTRODUCTION

On a part of Japanese snowy mountains, the upper montane vegetation zone is occupied by deciduous broad-leaved scrub, *Sasa* grassland and snowpatch meadow, instead of *Fagus crenata* forest which normally makes the montane vegetation zone in central and northern Japan. Previous biogeographical studies suggested that *F. crenata* trees can not establish their stand owing to the present heavy snowfall and/or prevailing strong winds of the winter monsoon in the upper montane zone of the snowy mountains (e.g., Miyawaki & *alii*, 1968; Sugita, 1988; Hatase & Okuda, 1999). In addition, the historical change of the vegetation should be considered for the establishment of the present-day vegetation landscape (e.g., Davis & *alii*, 1986; Slatyer & Noble, 1992).

The change in vegetation is recorded in the soil-stratigraphic sequence (Birkeland, 1984). Sasaki (2001) reported that a buried peaty soil layer can be seen widely in the deciduous broad-leaved scrub on Mt. Sumon-dake (37° 23' N, 139° 08' E; fig. 1), situated in the northern Echigo Mountains which are one of the Japanese snowy mountains. This fact indicates more extensive distribution of the snowpatch meadow on Sumon-dake than the present because such a peaty soil is considered to have been formed in the snowpatch meadow where snow-melting water is supplied from late-lying snowpatches until late July (e.g., Yamanaka, 1983).

This paper presents first the relation between slope processes and vegetation on mountain slopes of Sumon-dake to clarify the stands of the vegetation. Second, the stratigraphy of the peaty soil layer and its distribution on the slopes above the present-day upper limit of *F. crenata* forest are discussed to reconstruct the snowpatch meadow history. Changes in vegetation during the Holocene will be discussed on the basis of the peaty soil layer formation and the change in stands of vegetation.

STUDY AREA

Mt. Sumon-dake (1,538 m a.s.l.) is an andesitic volcano of latest Pliocene or middle Pleistocene (Niigata Prefectural Government, 1989). Sumon-dake and its surrounding areas are one of the heavy snowfall regions in Japan because of their location in the first range against the winter monsoon which blows from Japan Sea (fig. 1). Snow covers on the main ridges disappear in late June.

(*) *Institute of Geography, Graduate School of Science, Tohoku University, Sendai 980-8578, Japan*

I would like to express my appreciation to Professor Toshikazu Tamura of Rissho University for his guidance during the course of this study. I also thank Dr. Kaoru Kashima of Kyushu University and anonymous reviewers for their helpful suggestions.

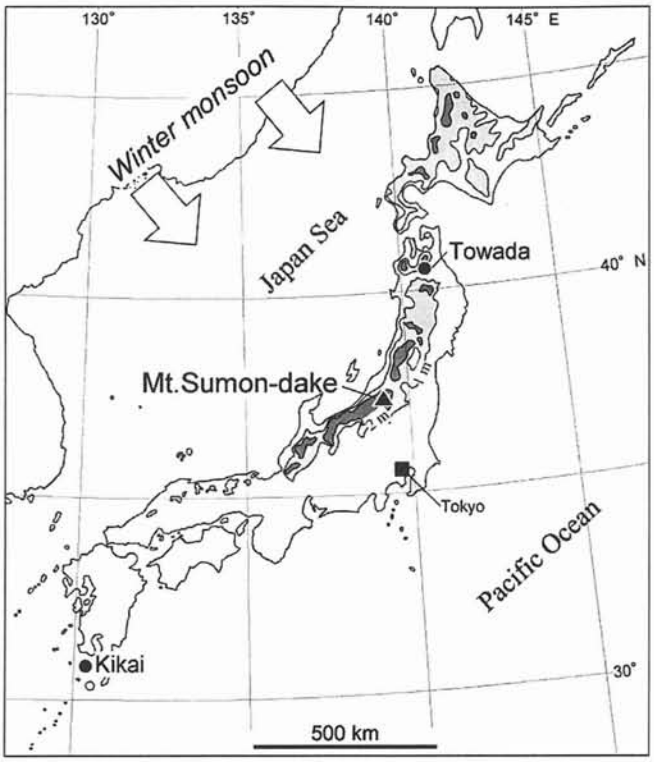

FIG. 1 - Location of Mt. Sumon-dake. Isolines indicate the mean maximum snow depth in Japan after the Japan Meteorological Agency (1972). Closed circles show the source volcanoes from which the time-marker tephras in Mt. Sumon-dake are derived.

METHODS

Surveyed soil pits were restricted to the slopes along the main ridge and the sub-ridges because the valley side steep slopes have thin and poor in organic topsoil. Two middle Holocene tephra layers are occasionally observed in the top soil on Sumon-dake (Sasaki, 2001). In the present paper, formation age of the peaty soil layer is determined by tephrochronological estimation using these two tephras in the peaty soil. The tephras were correlated with the known tephras on the basis of lithofacies, mineral composition, shape of volcanic glass shards, and refractive indices of volcanic glass shards and orthpyroxene phenocrysts, measured using RIMS86 (Kyoto Fission-Track Co. Ltd.) in the Institute of Geography, Tohoku University.

RELATIONSHIPS OF MOUNTAIN SLOPES AND VEGETATION

Characteristics of mountain slopes and vegetation were investigated first to clarify their relationship (figs. 2 and 3). The slopes around the summit are characterized by steep slopes of 30-40°or more, except the crest gentle slopes and the fossil snowpatch hollows. The steep slopes on leeward side of winter prevailing winds (westerly winds) are characterized by the development of avalanche chutes and avalanche furrows (fig. 4; Rapp, 1959; Sekiguchi, 1994). On these steep slopes, full-depth snow avalanches are thought to occur many times in every winter season. Besides, glides of the snowbank strongly act on these slopes. *F. crenata* forest, therefore, can not establish their stand on these slopes, and various pioneer shrubs, less than 2 m high, are dominant instead.

On the other hand, the windward steep slopes have little of geomorphic traces formed by snow avalanches. The surface of the slopes is covered by thin soil which is rich in mineral but poor in organic. Presently the significant slope processes for the surface condition on these slopes are not the snow avalanche, but the soil creep and gully erosion. *F. crenata* forests are remarkably confined to these steep slopes. *F. crenata* trees seem to be able to grow on these slopes because snow avalanche action is relatively less intensive there.

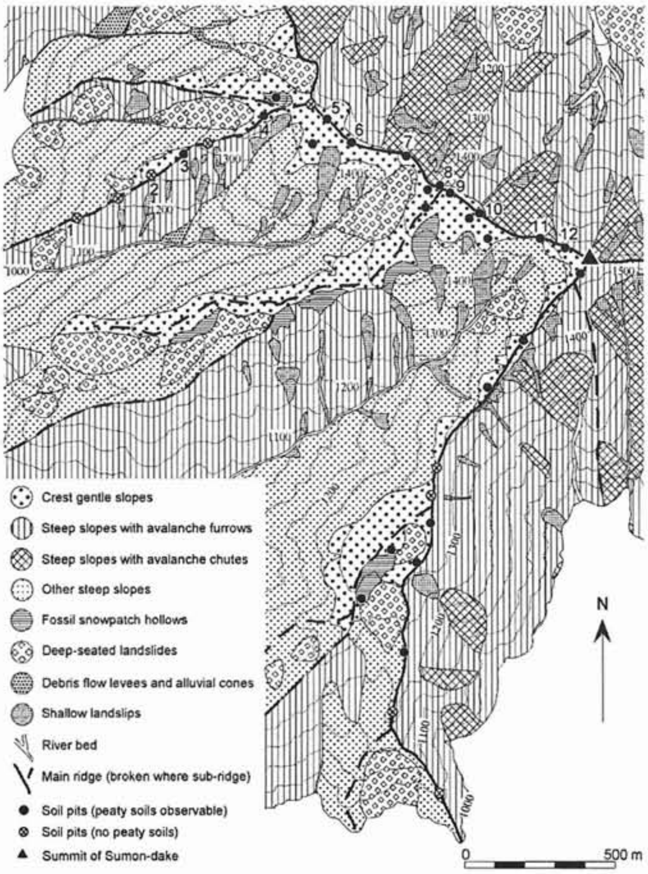

FIG. 2 - Geomorphological map of the study area and the location of soil pits. The soil pits with numerals are shown in fig. 5. This map were illustrated by the interpretation of the color aerial photographs (1:15,000 in scale) taken in 1976 by the Geographical Survey Institute.

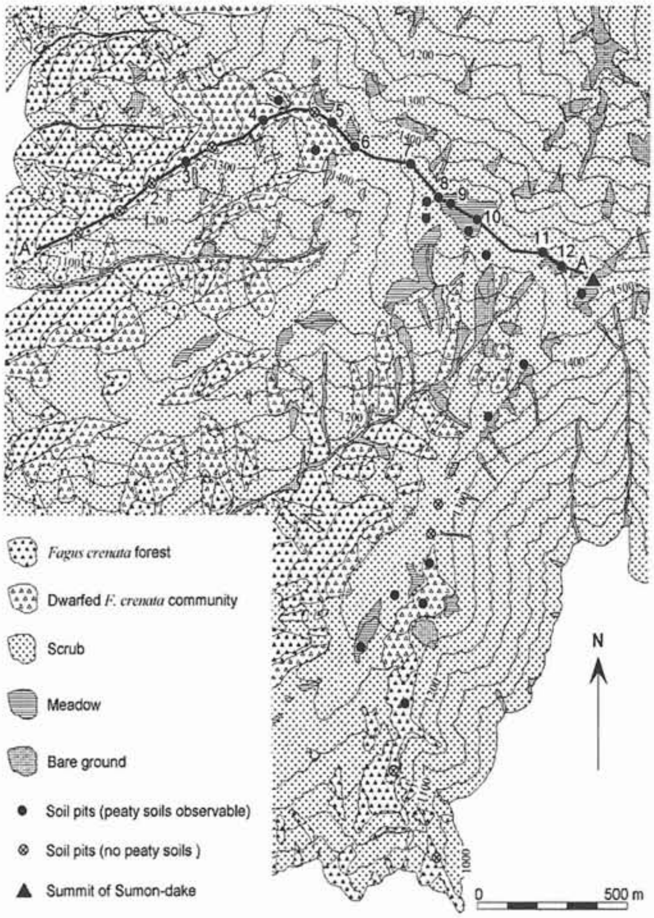

FIG. 3 - Vegetation map of the study area. Line A-A´ indicates the transection along the profiles presented in fig. 5-a. This map were prepared by the interpretation of the color aerial photographs (1:15,000 in scale) taken in 1976 by the Geographical Survey Institute.

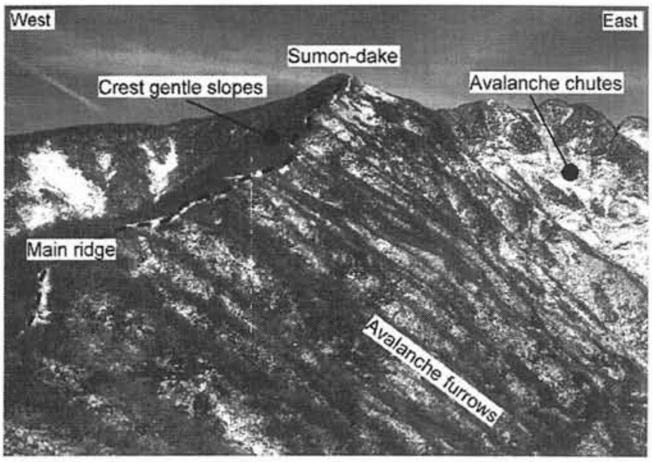

FIG. 4 - Southeast-facing slopes of Mt. Sumon-dake. The avalanche chutes have shallow U-shaped cross profiles mostly about 20 m across and several hundred meters long. The avalanche furrows show rectilinear gully forms with shallow U-shaped cross profiles mostly 3-5 m wide and a few hundred meters long along the direction of maximum slope angle. Both forms are developed in close relation to full-depth snow avalanche. Full-depth snow avalanches are thought to occur many times in winter season. Trees, therefore, can not establish their stand owing to snow avalanche action, and pioneer shrubs are dominant instead. The crest gentle slopes, generally less than 15°, are distributed on the windward slopes close to the main ridge. The crest gentle slopes are covered by scrub.

The crest gentle slopes, which are the debris-mantle slopes formed mainly by solifluction in the Last Glacial, are distributed on the windward slopes close to the main ridges (fig. 4). The fossil snowpatch hollows are also formed with a periglacial and nival processes during the Last Glacial. The crest gentle slopes and fossil snowpatch hollows are considered to be stable at present because the surface is mostly covered by an organic rich soil. On the crest gentle slopes above 1,200-1,300 m in altitude, *F. crenata* forest is replaced by dwarfed *F. crenata* community, and the upper limit of the community lies at 1,440 m in altitude. The crest gentle slopes between the mountain peak and 1,440 m in altitude are occupied by snowpatch meadows and deciduous broad-leaved scrub, composed mainly of *Quercus mongolica* var. *undulatifolia* which is known as major deciduous broad-leaved shrubs of the lower subalpine zone in the snowy mountains of Japan Sea side (Miyawaki & *alii*, 1968; Ishizuka, 1978). The present-day upper montane zone - subalpine zone boundary of Sumon-dake is judged to be 1,440 m in altitude.

SOIL STRATIGRAPHY

Soil survey on the mountain slopes revealed that the fossil snowpatch hollows and the crest gentle slopes, above the present-day upper limit of *F. crenata* forests, are widely covered with a peaty soil layer which contains well-decomposed fragments of herbaceous plant remains (figs. 2 and 5). The peaty soil layer with eluvial horizon is less than 30 cm thick, and directly covers the surface materials of the slopes. The layer is massive and brownish black (5YR2/2) or dark blown (7.5YR3/3) colored. These soil characteristics agree with the common features of the peaty soil layer in the subalpine zone of Japanese snowy mountains (e.g., Yamanaka, 1983; Kariya, 1994; Kariya & *alii*, 1996; Sasaki & Kariya, 2000).

The stratigraphy of organic soil layer can be divided into two types. One is composed entirely of peaty soil, observed only in the snowpatch meadow (pits. 10 and 12). The other, observed in the dwarfed *F. crenata* community and the scrub (pits 3 to 8, and 11), is composed of an upper humic loam layer without any plant remains and the lower peaty soil layer. The humic loam layer, with crumby structure, consists of brownish black (5YR2/1, 7.5YR3/1) silty clay loam or sandy clay loam. Although the boundary between the humic loam layer and the underlying peaty soil layer is generally sharp, the humic loam layer is locally accompanied with an eluvial horizon, brownish gray (10YR4/1) in color, at its base (pits. 4, 6, 8 and 11).

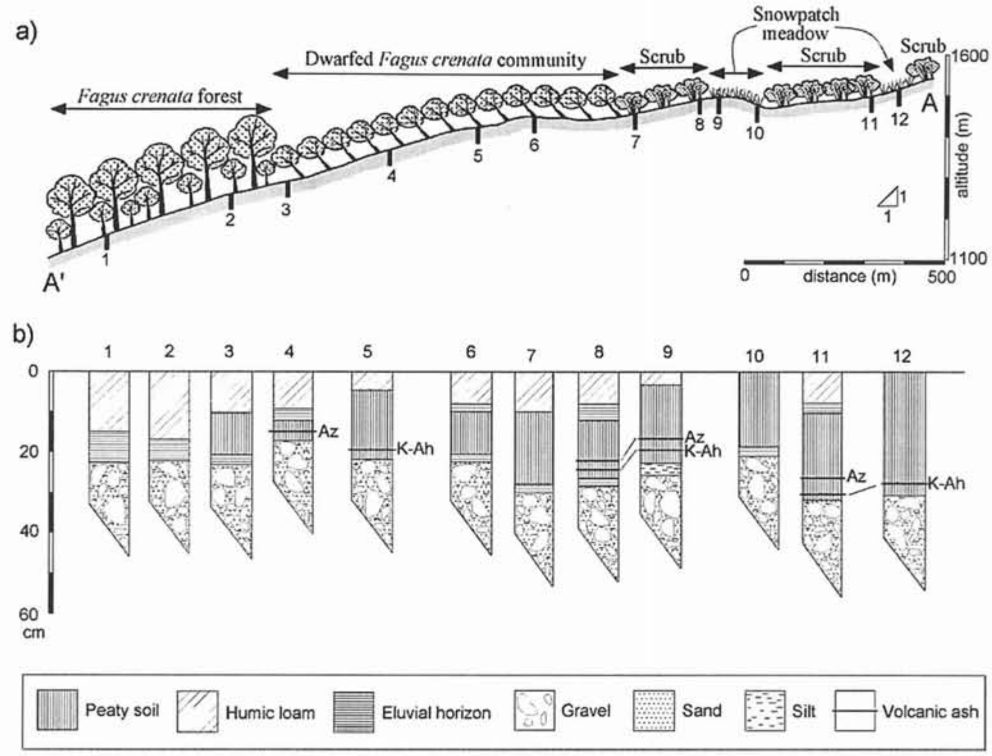

FIG. 5 - Topographic profile and columnar sections of the soil pits along the line A-A′. a) Topographic profile and vegetation arrangement on the line A-A′. Location of the line A-A′ is shown in fig. 3, b) Columnar sections of the soil pits. AZ: *Azuma* tephra (6,300 cal. yr BP), K-Ah: *Kikai-Akahoya* tephra (7,200 cal. yr BP).

On the other hand, the peaty soil layer is not identified in presently *F. crenata* forest (pits 1 and 2). There is a brown forest soil which consists of a humic loam layer as A horizon and underlying eluvial horizon.

Two thin tephra layers, composed mainly of fine ash, intercalate the lower part of the peaty soil layer. The upper one is the *Azuma* tephra (Az: 6,300 cal. yr BP; Saijo & Komatsubara, 1988) which was erupted from the Towada caldera about 360 km north of Sumon-dake. The lower one is the *Kikai-Akahoya* tephra (K-Ah: 7,200 cal. yr BP; Machida & Arai, 1978) which is one of the major Holocene widespread tephras in Japan.

DISCUSSION

The initiation of the peaty soil layer on the crest gentle slopes is older than 7,200-6,300 cal. yr BP because the lower parts of the peaty soil layer are commonly intercalated by Az tephra and K-Ah tephra (fig. 5). Especially, the base of the peaty soil layer in the pits 8, 9, and 11 are extrapolated to be 9,000-7,500 cal. yr BP from the accumulation rate of the peaty soil between Az tephra and K-Ah tephra. The peaty soil layer formation on most part of the crest gentle slopes started in the early Holocene. Periglacial processes have been active on the crest gentle slopes and these slopes were poor in vegetation in the age before the peaty soil layer began to develop (fig. 6), subsequently the snowpatch meadows covered the crest gentle slopes above 1,250 m in altitude in the early Holocene, indicated by the herbaceous peaty soil layer formation (fig. 6).

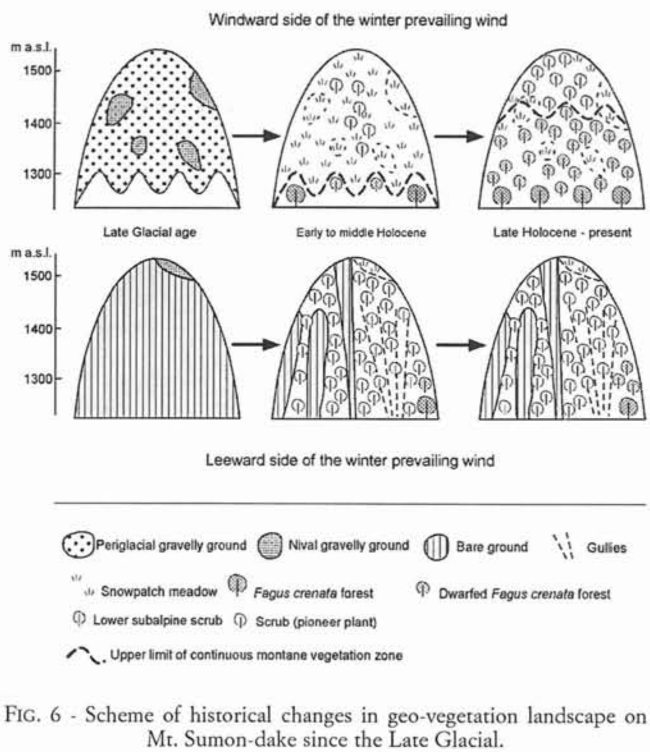

FIG. 6 - Scheme of historical changes in geo-vegetation landscape on Mt. Sumon-dake since the Late Glacial.

The peaty soil layer formation ended on most parts of the crest gentle slopes, and formation of the humic loam started instead (fig. 5). The change in pedogenic process is considered to occur in the late Holocene based on the stratigraphy of Az tephra and K-Ah tephra. The change in soil formation from the peaty soil layer to the humic loam layer suggests that the vegetation on the crest gentle slopes changed from the snowpatch meadow to the scrub. The widely distributed snowpatch meadows on the crest gentle slopes had continued to exist during the early to middle Holocene (fig. 6).

On the other hand, snow avalanche and snow glide are considered to have been working on the leeward steep slopes since 16,000 cal. yr BP when increasing in snowfall started on the mountain regions of Japan Sea side (Sakaguchi, 1978). In the early to middle Holocene, the upper limit of continuous montane vegetation area represented by *F. crenata* trees remained at 1,200-1,300 m in altitude (fig. 6), 100-250 m lower elevation than present, even though the upper limit of montane zone reached its present-day position on the other snowy mountains in response to the warming after the Last Glacial (e.g., Yamanaka, 1969; Tsukada, 1982). *F. crenata* trees could not easily expand their stand upward on the leeward steep slopes because snow avalanche and snow glide acted on the leeward steep slopes. The stands of *F. crenata* forest would have been thus restricted within the windward steep slopes. The slope conditions, strongly controlled by heavy snow accumulation, delayed upward extension of the *F. crenata* forest in the period of climatic warming since the Last Glacial termination. In the early to middle Holocene, the area of the present-day upper montane zone was, therefore, occupied by the snowpatch meadows instead of *F. crenata* forest.

FINAL REMARKS

This paper discusses the vegetation changes of the present-day upper montane vegetation zone through the Holocene on Mt. Sumon-dake on the basis of the soil stratigraphy and changes in the stands of vegetation.

The upper limit of the montane zone shifted upward in response to the warming after the Last Glacial. Its elevation in the early Holocene, however, was 100-250 m lower than present. The snowpatch meadows established on the above area of the montane zone, where is present-day upper montane zone, in the early Holocene. The widely distributed snow patch meadows continued to exist during the early to middle Holocene instead of *F. crenata* forest. The shifts of vegetation zone were strongly controlled by heavy snow accumulation since the Late Glacial.

REFERENCES

BIRKELAND P.W. (1984) - *Soils and Geomorphology*. Oxford, New York, 372 pp.

DAVIS M.B., WOODS K.D., WEBB S.L. & FUTYMA R.P. (1986) - *Dispersal versusclimate: Expansion of Fagus and Tsuga into the upper Great Lakes region*. Vegetatio, 67, 93-103.

HATASE Y. & OKUDA S. (1999) - *Relationship between distribution pattern of deciduous scrub, and topography and snow conditions on Mt. Sumon, in the Echigo Mountains*. Vegetation Sci., 16, 39-55. (in Japanese with English summary).

ISHIZUKA K. (1978) - *Subalpine vegetation of Japan affected by heavy snowfall*. In: *Papers on Plant Ecology to the Memory of Dr. Kuniji Yoshioka*. Society of Plant Ecology, Sendai, 404-428 (in Japanese).

JAPAN METEOROLOGICAL AGENCY (1972) - *Climatic Atlas of Japan. Vol. 2*. Japan Meteorological Agency, Tokyo (in Japanese).

KARIYA Y. (1994) - *Genesis of buried muck in the subalpine zone of Mount Gassan, snowy mountain in northern Japan*. Quat. Res. (Jpn), 33, 269-276 (in Japanese).

KARIYA Y., SASAKI A. & ARAI F. (1996) - *Initiation of alpine grassland and wet meadow soils on snowy high mountains in central Japan: a tephrochronological estimate*. Geogr. Rep. Tokyo Metropolitan Univ., 31, 105-117.

MACHIDA H. & ARAI F. (1978) - *Akahoya ash: A Holocene widespread tephra erupted from the Kikai caldera, south Kyusyu, Japan*. Quat. Res. (Jpn), 17, 143-163 (in Japanese with English summary).

MIYAWAKI A., OHBA T., OKUDA S., NAKAYAMA K. & FUJIWARA K. (1968) - *Pflanzensoziologische Studien über die Vegetation der Umgebung von Echigo-Sanzan u. Okutadami (Niigata-Präfektur und Fukushima- Präfektur)*. In: Nature Conservation Society of Japan (ed.), «Scientific Reports of Nature Conservation Society of Japan», 34, Nature Conservation Society of Japan, Tokyo, 57-152 (in Japanese with German summary).

NIIGATA PREFECTURAL GOVERNMENT (1989) - *Explanatory text of geological map of Niigata Prefecture, scale 1:200,000*. Niigata Prefectural Government, Niigata, Japan (in Japanese with English summary).

RAPP A. (1959) - *Avalanche boulder tongues in Lappland*. Geogr. Ann., 41, 34-48.

SAIJO K. & KOMATSUBARA T. (1988) - *The middle Holocene tephras on the Iide and Asahi Mountains and their implication to slope chronology*. Journ. Geogr. (Jpn), 97, 69-76 (in Japanese with English summary).

SAKAGUCHI Y. (1978) - *Climatic changes in central Japan since 38,400 y BP: viewed from palynological study on Ozegahara deposits*. Bull. Dep. Geogr. Univ. Tokyo, 10, 1-10.

SASAKI A. (2001) - *Formation of peaty soil layer along the main ridge of Mt. Sumon-dake in central Japan*. Sci. Rep. Tohoku Univ. 7th Ser. (Geogr.), 51, 19-34.

SASAKI A. & KARIYA Y. (2000) - *Initiation age of a peaty soil layer in the subalpine zone of Mount Tairappyo, the Mikuni Mountains, central Japan*. Quarterly Journ. Geogr., 52, 283-294 (in Japanese with English summary).

SEKIGUCHI T. (1994) - *Geomorphological feature and distribution of slopes in heavy snow regions in Japan where full-depth snow avalanches occur*. Journ. Jap. Soc. Snow and Ice, 56, 145-157 (in Japanese with English summary).

SLATYER R.O. & NOBLE I.R. (1992) - *Dynamics of montane treelines*. In: Hansen A. J. & di Castri F. (ed.), «Landscape boundaries: consequences for biotic diversity and ecological flows». Springer-Verlag, New York, 346-359.

SUGITA H. (1988) - *Environmental factors and their effects on the distribution of plant communities in Mt. Asakusa, a mountain with deep snow: with special relation to the growth of Fagus crenata I: Relationship between snow depth and the distribution pattern of plant communities*. Jap. Jour. Ecology, 38, 217-227 (in Japanese with English summary).

TSUKADA M. (1982) - *Late-Quaternary development of the Fagus forest in the Japanese archipelago*. Jap. Jour. Ecology, 32, 113-118.

YAMANAKA H. (1983) - *Radiocarbon ages of alpine wet-meadow soil on Mt. Iide*. Quat. Res. (Jpn), 21, 315-321 (in Japanese with English summary).

YAMANAKA M. (1969) - *Palynological studies of peat moors in Mt. Chokai*. Ecol. Rev., 17, 203-208.