# A PRELIMINARY STUDY ON THE EFFECTS OF PYROCLASTIC FALL DEPOSIT ON THE FOREST ECOSYSTEM IN SOUTHWESTERN HOKKAIDO, JAPAN

**Shuichi OKA and Sadao TAKAOKA**

*Abstract* In southwestern Hokkaido, volcanic activities were high during historical times. For examination of their effects on forest ecosystem, we conducted preliminary survey using a dendroecological technique. Tree-ring samples were collected mainly in the southern part of the Ishikari Lowland where some layers of pyroclastic fall were found. The number of tree-rings was counted and tree-ring widths were measured. As a result, we could distinguish from the 1739 tree ring measurements the effect of eruption with its subsequent Ta-a volcanic deposition. This proves that the effect on tree growth changed in proportion to distance from the origin of the pyroclastic fall.

**Key words:** forest ecosystem. pyroclastic fall, dendroecology. southwestern Hokkaido

## 1. Introduction

Spatial patterns of forest vegetation are formed under the influence of volcanic activities. Eruptions over the last several decades have affected forest development directly. For example, forest stands are destroyed by lava streams, pyroclastic flows and lahar, and plant succession starts in each of the damaged stands after the disturbance. As a result, different succession-stage stands are formed on each newly damaged land. The particular type of vegetation varied depending on the type of land surface. Fires accompanied by volcanic activities also destroy forests. Volcanic gases ($SO_2$, HCl and HF) leaving craters damage nearby vegetation, causing chemically tolerant species to be establish there.

Present vegetation structures are indirectly affected by past volcanic activities which are out of the time scale for forest succession. Flat surfaces, such as lava plateaus, provide poor draining sites, where no forest, but scrub, meadow or moor is often formed. Variations in the lithology of surface materials (pumice, scoria and volcanic rock) provide plants with various edaphic conditions such as infiltration capacity and water-folding capacity.

Mosaic vegetation patterns are formed by not only volcano-forming processes but also the dissection processes. Surface erosion, landslides, and forming talus occur mainly at sites of specific bed rocks and topographic positions, and they disturb forest stands or create variations in edaphic conditions.

Several studies on post-eruption succession have been conducted in Japan in locations within volcanic zones (*e.g.*, Tagawa, 1964, 1965; Yoshioka, 1966; Rivière, 1986; Tsuyuzaki, 1987, 1991; Fujimoto, 1993). Most of them, however, were focused on the early stage of succession during the first few years or decades after an eruption. Long-term effects of volcanoes have rarely been analyzed. Studies on the differentiation of vegetation patterns on Mt. Fuji (Nakamura, 1992) and Hachijo-Island (Kamijo and Okutomi, 1993) are very interesting since the relationship between long-term vegetation history and the lithology of surface materials are discussed. These studies would be more stimulating if the slope-development processes had also been studied.

As for volcanic effects on vegetation, the following two points are to be examined in the future. 1)The interrelationship between the actual vegetation structure and the historical development of volcanoes should be clarified systematically. Machida *et al.* (1990) reconstructed the c. 1000 yr. BP. eruption of the Changbai volcano located on the Chinees-Korean border, and made it clear that the past explosive activities were closely related to the processes of post-eruption regeneration. As with this work, it is preferable that the origin of vegetation structure is analyzed with reference to the long-term effects of volcanic activites. 2)The effects of pyroclastic fall deposit on vegetation should also be studied in the surrounding areas of volcanoes (*e.g.*, Yamaguchi, 1983). Pumice and scoria are often transported by wind and fall on areas a long distance from their eruption source. It is necessary to analyze their long-term effects on the vegetation structure in such non-volcanic regions.

The present study aims at dealing with the latter issue. This is a preliminary report on the effects of eruption on the forest vegetation using a dendroecological method.

## 2. Survey Area

Among volcanic activities during historical times of Japan, none were more dramatic in their intensity in terms of scale and frequency than the explosive eruptions of various volcanoes as seen in the eruption of Mt. Komagatake in Hokkaido in 1640. The main survey areas were set in a range within which the influence of eruptions of Mt. Komagatake, Mt. Tarumae and Mt. Usu, in the southwestern part of Hokkaido, prevails. Distinct tephra layers accompaning eruption which should have directly affected forest vegetation and human life were Ko-d (1640), Ko-$c_2$ (1694), Ko-$c_1$ (1856), Ko-a (1929), Ta-b (1667), Ta-a (1739), and Us-b (1663) (Machida and Arai, 1992).

In the southern part of the Ishikari Lowland where the survey had been carried out, there are summer-green broad-leaved forests, such as *Quercus mongolica* var. *grosseserrata*, *Ulmus japonica*, *Cercidiphyllum japonicum*, *Acer mono* var. *glabrum*, and *Tilia japonica*, while in somewhat mesic sites, stands are dominated by *Q. mongolica* var. *grosseserrata*, *Populus maximowiczii*, *A. mono* var. *glabrum*, and *Fraxinus mandshurica* var. *japonica*. As the altitude rises, a mixture of needle-leaf and broad-leaf forests

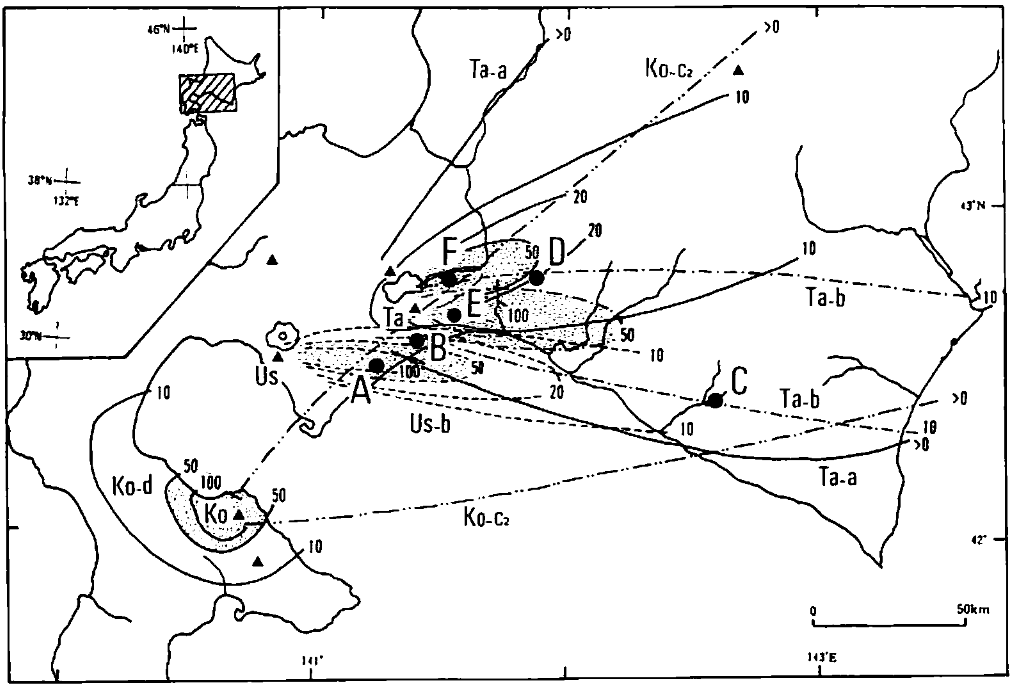


Fig. 1 Sampling points of tree-rings
A: Kuttara; B: Shiraoi-Poroto; C: Shizunai; D: Atsuma: E: Tomakomai; F: Maruyama
Sampling points are added to the isopach map (Machida and Arai, 1992) of tephra layers.

intermingling *Q. mongolica* var. *grosseserrata*, *A. mono* var. *glabrum*, *T. japonica* with *Picea jezoensis*, *Abies sachalinensis* gradually occur. In the national forest of Tomakomai, Shizunai, Shiraoi, *etc.*, and in the provincial forest at Atsuma situated within the survey areas grow gigantic trees in great numbers. Some were more than 70 cm in diameter at breast height and several ten meter high trees had an estimated age of more than two hundred years.

## 3. Method

This study examined the eruption periods as well as their consequences by using the dendrochronological technique. To be more specific, we looked for any clues as to whether the two eruptions of Ta-b in 1667 as well as that of Ko-$c_2$ in 1694 are discernible in the growth rings of trees. We also examined both the scale and range of influence of the eruption of Mt. Tarumae in 1739 based on secular changes in tulle width of tree-rings.

At first, old gigantic trees that might show the influence of eruptions in and around Mt. Tarumae were identified. Next, tree-ring samples were collected from those trees. Samples in forms of discs were cut from existing tree stumps as much as possible. In case of necessity, however, core samplings were made by means of an increment borer. In

1991, we obtained a part of disc of the *Q. mongolica* var. *grosseserrata* tree having double roots which were cut down in 1980 at the northwestern foot of Mt. Tarumae and is now in the possession of the Tomakomai City Museum. In 1992, increment cores were collected from gigantic trees that were more than 70 cm in diameter at a breast height level in and around the Kuttara Lake, the Shiraoi-Poroto Lake and the Shizunai Lake. In 1993, samplings of stump discs were gathered in the national forests along the basin of the Tomakomai River and the forests of Atsuma Town owned by Hokkaido prefectural government.

The number of tree-rings was counted and their width was measured. This was done using a binocular microscope with reading apparatus attached. It has an accuracy of 0.001 mm. The time series of the tree-ring data was compared and data characteristics was examined.

Species was limited to *Q. mongolica* var. *grosseserrata* as much as possible at the time of collections in order to exclude differences caused by species growth variation. In all cases, the place where samples were collected was approximately 50 cm to 100 cm above ground level; therefore, some errors in terms of real age of trees exist.

## 4. Results and Discussion

Almost all samples showed remarkable growth and most of the trees grew less than 100 years. However, the estimated ages of *Quercus mongolica* var. *grosseserrata* around the Tomakomai River and Atsuma Town exceeded 272 years, 294 years, 299 years, 313 years, 315 years, and 329 years. The ages of *Q. mongolica* var. *grosseserrata* collected in Kuttara and Shizunai also exceeded 365 years and 386 years. Among the samples collected, Table 1 shows *Q. mongolica* var. *grosseserrata* exceeding 200 years. The respective sites where collections were made are expressed in Fig. 1. This was written

**Table 1** Tree-ring samples of *Quercus mongolica* var. *grosseserrata*

| Locality | Lumber year | Number of tree rings | diameter (cm) |
|---|---|---|---|
| Shizunai | 1992.11 | 386 | * |
| Kuttara | 1992 | 365 | * |
| Tomakomai | 1992.10 | 299 | 99 |
| | 1992.10 | 294 | 90 |
| | 1992.10 | 272 | 86 |
| Atsuma | 1992.10 | 329 | 86 |
| | 1992.10 | 315 | 77 |
| | 1992.10 | 313 | 72 |
| Shiraoi-Poroto | 1992. 9 | 259 | 111 |
| | 1992. 9 | 208 | 88 |
| Maruyama | 1980 | 288 | * |
| | 1990.12 | 257 | * |

*: Unmeasured

using an isopach map (Machida and Arai, 1992) delineating the major tephra layers derived from some volcanoes of southwestern Hokkaido during historical times. Although the detailed locations of sampling points were unspecified, approximate localities are shown in Fig. 1.

The degree of influence on the growth of trees expected from their approximate relationship with an isopach line and its respective tephra as denoted in Fig. 1 is as

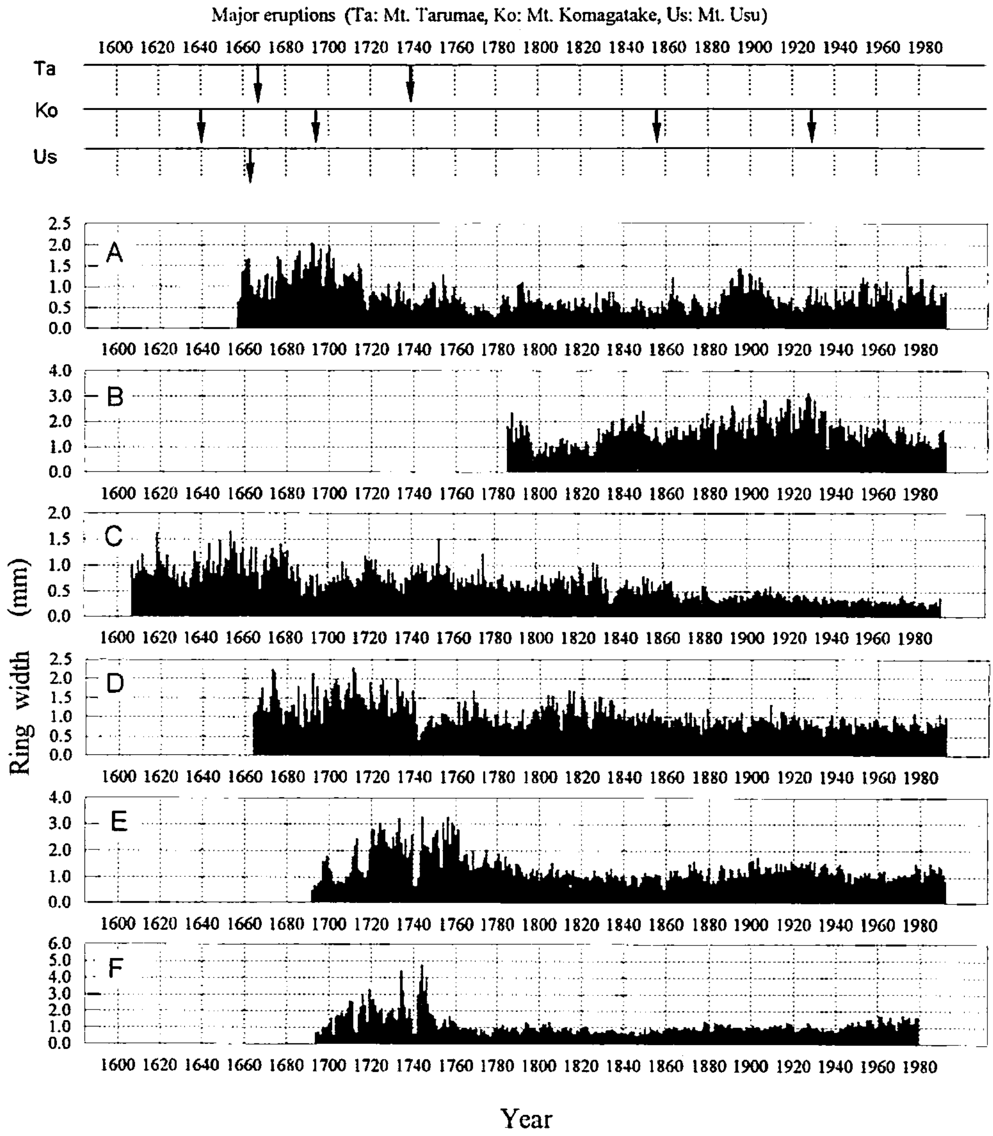


Fig. 2 Secular changes of tree-ring width
Localities are shown in Fig. 1. (redrawn from Oka, 1994)

follows. Mt. Tarumae Ta-b (1667): 1)Tomakomai, 2)Maruyama, Atuma, 3)Shiraoi, Shizunai, 4)Kuttara; Ta-a (1739): 1)Maruyama, 2)Tomakomai, Atsuma, 3)Shiraoi, Shizunai, 4)Kuttara; Mt. Komagatake Ko-d (1640): unidentified; Ko-$c_2$ (1694): 1)Kuttara, Shiraoi, Tomakomai, 2)Maruyama, Atsuma, Shizunai; Mt. Usu Us-b (1663): 1)Kuttara, 2) Shiraoi, 3)Tomakomai, 4)Shizunai, 5)Maruyama, Atsuma. In reality, however, one cannot simply determine the relationship between tree ring growth and tephra layer thickness, since tree ring widths include differences in tree growth among individuals and influence of edaphic conditions.

In Fig. 2 secular changes of the tree-ring width are shown noting individual samples which were the oldest at respective tree-ring collection sites. In all cases, no elimination was done on changes considered as having been induced by individual characteristics. In this time series, therefore, there existed changes based on individual characteristics as well as changes based on climate. Even with this taken into consideration, one can find some characteristic patterns. In Kuttara, for example, one can recognize periods of diminished growth corresponding to Us-b in 1663. Samples able to be traced back to this period were found also in Shizunai. The growth rings of trees calculated to be year 1668 and 1669 manifest a diminished growth. Judging from those growth rings, the eruption Ta-b was considered to have the most likely influence.

While one can recognize the influence of the eruption of Mt. Komagatake of 1694 at Kuttara, Shizunai and Atsuma, there was an error of one to two years in the respective periods of the diminished growth. In particular, the influence of the eruption of Mt. Tarumae Ta-a in 1739 is worthy of note. If a maximum of two or three year error is allowed, all samples showed worsening trend of growth except Shiraoi. Shiraoi trees established themselves after the 1739 eruption. The growth increment decreases before and after 1739 in order of Kuttara, Shizunai, Atsuma, Tomakomai and Maruyama. Viewing the deviation between the minimum value of tree-ring width at that time and the 11-year moving average value nipping 1739 at the center, it follows that the deviation was 0.2 mm at Kuttara; Shizunai, 0.3 mm; Atsuma, 0.6 mm; Tomakomai, 1.2 mm; and Maruyama, 1.8 mm. These are regarded as one sort of index pointing out the influence of eruption of Ta-a in 1739. In this case, as forecasted previously, the degree of influence of eruptions affecting the tree-ring width come up to the thickness of tephra layer. In order to clarify this relationship, it is necessary to check the relationship to the thickness of tephra layer at individual points.

## 6. Summary

As stated above, in this study, a prospect was established where the identification of periods of eruptions was made judging from variation in tree-ring width as well as making estimates on the influence of eruptions. It is fervently desired hereafter that a large repository of tree-ring samples should be stored for use in statistical research as well as for making estimates of diminished tree growth quantitatively. It would also be beneficial to collect tree-ring samples in the districts unaffected by eruptions to develop a standard growth curve line. Moreover, in order to extensively discuss the effect on forests upon which volcanic ash falls. it is necessary that the dendroecological method should parallel mapping of plant communities by means of aerial photograph analysis. Thus, in order to discuss the influence that gave an impact on human life, there are left many more tasks to be examined including an introduction of archaeological style as well.

## Acknowledgements

We would like to thank Professor Hiroshi Machida of Tokyo Metropolitan University for giving us an opportunity to do this study. We are grateful to Mr. Kazuo Satoh, Curator of the Tomakomai City Museum, for providing the tree-ring samples and the archaeological data to us, and for supporting us in conducting our field work.

This paper is dedicated to Professor Hiroshi Machida in commemoration of his retirement from Tokyo Metropolitan University.

## References Cited

Fujimoto, S. (1993): Successional changes of forest vegetation during 14 years since the 1977 eruption of Mt. Usu: especially on response patterns of tall trees. *Jpn. J. Ecol.*, 43, 1-11.**

Kamijo, T. and Okutomi, K. (1993): Distribution of *Castanopsis* forest and its causal factors on Hachijo-jima in the Izu Island. *Jpn. J. Ecol.*, 43, 169-179.**

Machida, H. and Arai, F. (1992): *Kazan-bai Atorasu: Nihon-rettou to sono Shuhen (Atlas of Tephra in and around Japan).* Univ. Tokyo Press, Tokyo, 276p.*

Machida, H., Moriwaki, H. and Zhao, D. (1990): The recent major eruption of Changbai volcano and its environmental effects. *Geogr. Repts. Tokyo Metropol. Univ.*, 25, 1-20.

Nakamura, T. (1992): Succession and differenciation of forest communities in the subalpine region of Mt. Fuji. *Bull. Tokyo Univ. For.*, 87, 159-173.

Oka, S. (1994): *Jumoku Nenrin kara Yomitorareru Kikou no Hensen to Funka no Rekisi* (*Climatic changes and volcanic events read in secular change of tree rings*). Machida, H. and Moriwaki, H. eds.: *Kazan Funka to Kankyo, Bunmei* (*Effects of Volcanic Eruptions on Environment and Civilization*). Shibunkaku-shuppan, Kyoto, 79-97.*

Rivière, A. (1986): Properties of the new volcanic substrate of Mt. Usu with regards to natural revegetation. *Environ. Sci. Hokkaido*, 9, 89-112.

Tagawa, H. (1964): A study of volcanic vegetation in Sakurajima, southwest Japan. I. Dynamics of vegetation. *Mem. Fac. Sci. Kyushu Univ., Ser. E (Biol.)*, 3, 165-228.

Tagawa, H. (1965): A study of volcanic vegetation in Sakurajima, south west Japan. II. Distributional pattern and succession. *Jap. J. Bot.*, 19, 127-148.

Tsuyuzaki, S. (1987): Origin of plants recovering on the volcano Usu, northern Japan, since the eruptions of 1977 and 1978. *Vegetatio*, 73, 53-58.

Tsuyuzaki, S. (1991): Species turnover and diversity during early stage of vegetation recovery in the volcano Usu, northern Japan. *J. Vegetation Science*, 2, 301-306.

Yamaguchi, D. K. (1983): New tree-ring dates for recent eruptions of Mount St. Helens. *Quat. Res.*, 20, 246-250.
Yoshioka, K. (1966): Development and recovery of vegetation since the 1929 eruption of Mt. Komagatake, Hokkaido. *Ecol. Rev.*, 16, 271-292.

(*: in Japanese, **: in Japanese with English abstract)