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Influences of the Vast Eruption of Kikai Caldera Volcano in the Holocene Vegetational History of Yakushima, Southern Kyushu, Japan

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Pollen analytical study of the Hananoego moor in Yakushima revealed the drastic influences of the volcanic eruption on the Holocene vegetational history in Yakushima. Dense forest mainly composed of *Cryptomeria japonica, Buxus, Quercus Cyclobalanopsis, Symplocos* and *Trochodendron aralioides* grew surrounding the Hananoego moor before the eruption of the Kikai caldera volcano. This forest, including the giant Japanese cedar (*Yakusugi*), was destroyed by the vast pyroclastic flow deposit from the Kikai caldera volcano which erupted 6300 years B.P.

Keywords: POLLEN ANALYSIS, YAKUSHIMA, KOYA PYROCLASTIC FLOW DEPOSIT, VEGETATIONAL HISTORY

INTRODUCTION

Yakushima is a small island located at the southern tip of the Japanese archipelago (Fig. 1) and has specific plant communities. The giant Japanese cedar (*Cryptomeria japonica* D. Don) called *Yakusugi*, some of which are more than 3,000 years old (Plate 1), is a typical species of this island. Mean annual temperature is 18°C and mean monthly temperature in January is 10°C and in August is 27°C. Mean annual precipitation during the last 30 years has been 3,800mm and occasionally the annual precipitation exceeds 10,000mm.

Mt. Miyanoura is the highest peak (1,935m) on this island and the Hananoego moor (30°18′30″ N. Lat., 130°30′45″ E. Long.) is located near the summit of this mountain at 1,630m in altitude.

The first palynological study of the Hananoego moor was conducted by Miyai (1938) and was followed by Takeoka (1971). The present author also succeeded in obtaining soil samples from the Hananoego moor in May, 1983 and carried out pollen analysis.

The Kikai caldera volcano (Fig. 1) erupted 6,300 years B.P. and was followed by the vast Kōya pyroclastic flow deposit and the Akahoya volcanic ash fall (Machida 1977). It is surmised that this eruption might have caused severe destruction of the vegetation of Yakushima. In this report, the Holocene vegetation history of Yakushima will be discussed in relation to the influences of the eruption of the Kikai caldera volcano, mainly from evidence based on the results of pollen analysis from the Hananoego moor.

Plate 1 Giant Japanese Cedar (*Yakusugi*) which grows in Yakushima.

SITE AND STRATIGRAPHY

The Hananoego moor is located in a small valley bottom about 100m in length and 40m in width (Fig. 2. Plate 2). Present vegetation near the Hananoego moor was studied by Miyawaki (1980) who reported the dominance of tall trees such as *Cryptomeria japonia, Trochodendron aralioides* and *Symplocos myrtacea* on the mountain slope over shrub trees such as *Rhododendron metternichii* var. *yakushimanum* and *Juniperus chinensis* var. *sargentii*. In the moor, hygrophytes such as *Eriocaulon hananoegoensis, Utricularia yakushimensis, Rhynchospora fujiiana, Carex omiana* var. *yakushimana* and *Sphagnum papillosum* form the characteristic plant communities. Main elements of the evergreen oak forest (laurel forest) such as *Castanopsis cuspidata, Quercus salicina, Q. acuta, Pasania thunbergii* and *Distylium racemosum* cannot grow at an altitude higher than 1,200m. Instead of these evergreen broadleaved trees, deciduous broadleaved trees such as *Stewartia monadelpha, Kalopanax pictus* var. *lutchuensis, Sorbus commixta, Viburunum furcatum* and

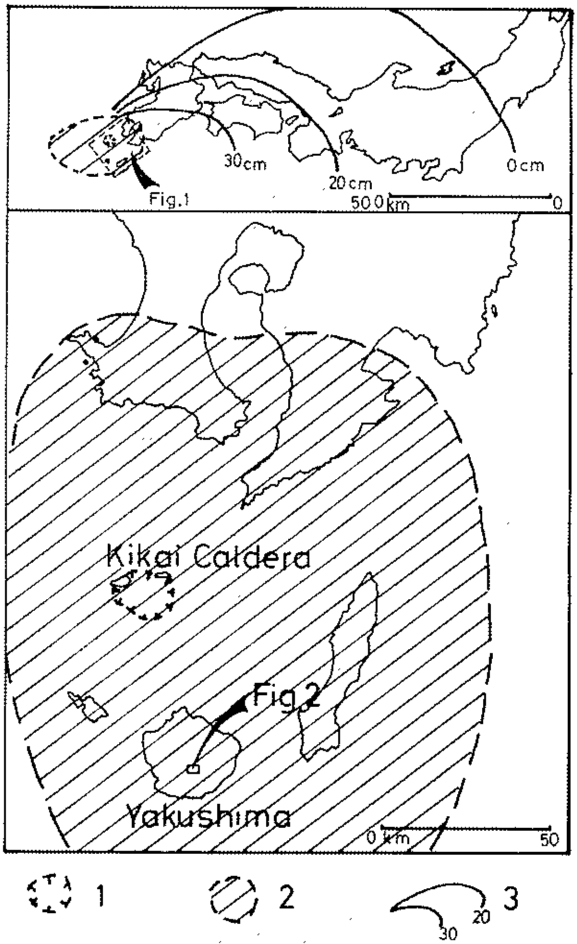

Fig. 1. Location of Yakushima and the Kikai caldera.
1. Kikai caldera. 2. Koya pyroclastic flow deposit.
3. Akahoya volcanic ash.

Acer sieboldianum thrive at altitudes above 1,200m, mixing with *Cryptomeria japonica, Abies firma, Tsuga sieboldii* and *Trochodendron aralioides*.

The samples for pollen analysis were collected using a Hiller type borer. A schematic cross section of this moor is shown in Fig. 3. The highly humified peat develops on the humic gravel, which includes the redeposited Kōya pumice. Maximum thickness of this highly humified peat is 1.5m and we will call this peat "New Peat" and give it the name of New Hananoego moor. The humic gravel is about 40cm and lies discordantly on the base rock of granite.

We found in Loc. 1 that buried decomposed peat underlay the primary Kōya pumice which erupted some 6,300 years B.P. The thickness of the buried peat is about 25cm and we will call this deposit "Old Peat" and give it the name of Old Hananoego moor.

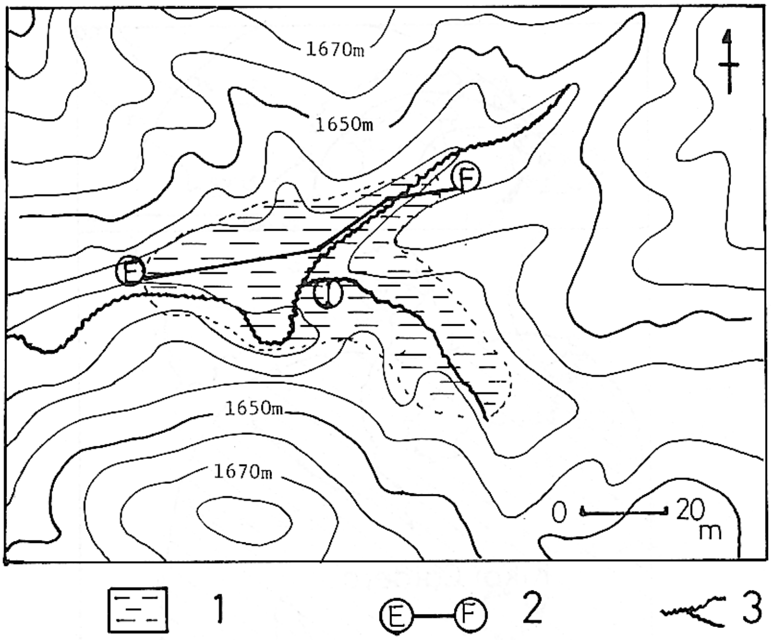

Fig.2. The Hananoego moor and the location of the cross section in Fig. 3.
1. Moor. 2. Cross section. 3. River.

Plate 2 The Hananoego moor.

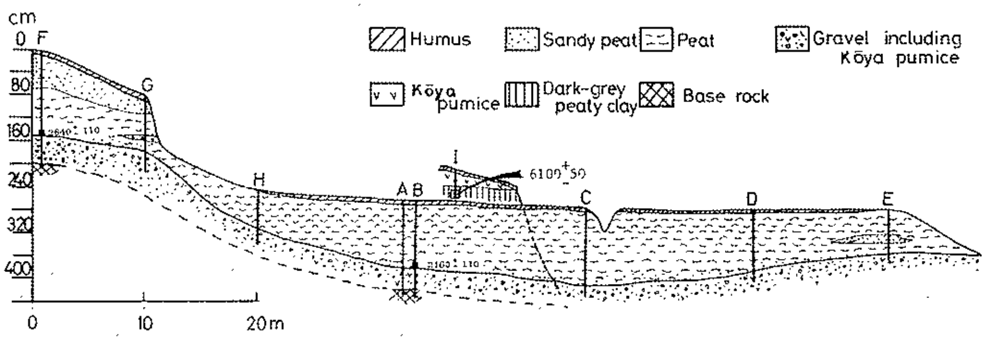

Fig.3. Schematic cross section of the Hananoego moor. Location of the cross section see Fig. 2.

RADIOCARBON DATING

The samples for radiocarbon dating were collected from three points. Two were measured from the bottom of the New Peat and one from the Old Peat. The results of radiocarbon dating are shown in Figs. 3, 4. According to the results of dating, the New Hananoego moor was formed about 2,500 years B.P. and Old Hananoego moor was destroyed around 6,100 years B.P. by the deposition of the Kōya pyroclastic flow deposit. The date obtained for the Old Peat is slightly younger than the expected age, as the eruption of the Kōya pyroclastic flow deposit occurred about 6,300 years B.P. (Machida and Arai, 1983).

METHOD OF POLLEN ANALYSIS

Palynomorphs were separated from the sediment matrix by the heavy liquid flotation method described by Faegri and Iversen (1964). The processing sequence is as follows: measuring wet volume, KOH (10%) treatment, wash, float (zinc chloride heavy liquid flotation; specific gravity 2.0), HCL (1%) treatment, wash, dehydration (acetic acid), acetolysis (boiled for three min. in water basin in a solution of one part concentrated sulfuric acid and nine patrs acetic anhydride), dehydration, wash, mount.

The materials were examined at 400× magnification and, when necessary, oil immersion was used. Generally more than 500 pollen grains were identified in each sample.

In addition to the observation using the light microscope, the samples were also studied using SEM. Residual materials were fixed by Carnoy's fluid (three parts alcohol and one part acetic acid) for one hour. The fixed material was washed with alcohol and then fixed by isoamylacetate for 30 min. A drop of the material was put on a brass stage and allowed to dry naturally, then coated by Au-Pd target for two min. in the Ion Sputter Fine Coat.

The pollen diagram (Fig. 4) was constructed in terms of percentages of the total tree pollen. Representative fossil pollen grains are shown in Plates 3 and 4.

POLLEN MORPHOLOGY OF *TROCHODENDRON ARALIOIDES*

Previous works by Miyai (1938) and Takeoka (1971) reported high frequency values of *Salix* and *Trochodendron*. However, *Salix* is not a dominant genus in the present plant community in the Hananoego moor. The pollen frequencies of *Trochodendron aralioides*, a dominant element in the present vegetation, also show high frequencies. One of the difficulties in the discussion of the Holocene vegetation history in Yakushima, is that the pollen types of *Salix* and *Trochodendron* have some points of similarity. Careful observation is needed for the identification of the two pollen types. The author reports the frequent occurrence of fossil grains comparable with *Trochodendron aralioides* in the Holocene deposit in the Hananoego moor.

Well-preserved pollen grains comparable to that of *Trochodendron aralioides* were recovered from all samples. The size, details of exine structure and ornamentation, and the morphology of the colpus of these fossil pollen specimens, are closely matched by those characteristics found in modern pollen of *Trochodendron aralioids*.

Pollen morphology of modern Trochodendron aralioides(Plate 5)

Specimen examined: The specimen was collected from Mt. Tōgō, Yuki-cho, Saeki-gun, Hiroshima Prefecture in 1983 by Dr. Y. Yoshino of the Department of Biology, Faculty of Science, Hiroshima University.

Pollen-class: 3 colporate.

Aperture: Colpus is 3–1.5μ in width and 22–17μ in length, and relatively wide and sunken. Pore is indistinct.

Exine: Exine is thick. Sexine is thicker than nexine. Sexine is 1.5μ and nexine is 1–0.7μ; baculae are $1 \times 1.5\mu$.

Ornamentation: Ornamentation is reticulate. Muri are 0.7–0.5μ in width. Lumina are indeterminate in shape. Lumina become smaller in size toward colpus, ranging from 1 to 0.5μ in diameter.

Outline: Equatorial view is elliptical and sometimes circular. Polar view is circular.

Measurement: Equatorial view is 24–19μ and polar view is 24–19μ.

Pollen morphology of fossil Trochodendron aralioides (Plates 3 and 4)

Specimen examined: The specimen was collected from the Holocene deposit taken from the Hananoego moor, Yaku-cho, Yakushima, Kagoshima Prefecture. Fossil pollen for measurement was collected from depths of 170, 150, 130, 100, 50 and 30cm.

Pollen-class: 3 colporate.

Aperture: Colpus is relatively wide and sunken, 5–2.5μ in width and 20–15μ in length. Pore is indistinct.

Exine: Exine is thick. Sexine is thicker than nexine. Sexine is 1.5–1μ, nexine is 1–0.7μ; baculae are $1 \times 1.5\mu$.

Ornamentation: Ornamentation is reticulate. Muri are 0.5μ in width. Lumina are indeterminate in shape and become smaller toward the margin of the colpus, ranging from 2 to 0.5μ in diameter.

Outline: Equatorial view is elliptical and sometimes circular. Polar view is circular.

Measurement: Equatorial view is 22–17μ and polar view is 26–21μ.

RESULTS OF POLLEN ANALYSIS

The pollen diagram (Fig. 4) is divided into three local pollen zones, from the lower upward: Pollen zones I, II and III.

Pollen zone I: This zone is characterized by high values of *Cryptomeria*, constituting more than 30.8% of the total tree pollen, while *Buxus* is 12.3%, *Quercus Cyclobalanopsis* 6.9%, *Symplocos* 20.4% and *Trochodendron aralioides* 11.3%. Warm temperate trees such as *Castanopsis, Myrica* and *Podocarpus* also show the highest frequencies throughout this section.

Pollen zone II: This zone corresponds with the upper part of the Old Peat, Kōya pyroclastic flow deposit and gravel. *Cryptomeria, Buxus, Quercus Cyclobalanopsis, Castanopsis* and *Podocarpus* decrease upward. *Cryptomeria* decreases from 30.8% to 9.6% of the total tree pollen, while *Symplocos, Rhododendron* and *Trochodendron aralioides* increase. These trends indicate the expansion of open lands which were formed by the fall of volcanic ash from the Kikai caldera volcano. After the fall of the ash, the Kōya pyroclastic flow was deposited. We could not discover any remains of pollen from the Kōya pyroclastic flow deposit. After the deposition of the Kōya pyroclastic flow, *Symplocos, Rhododendron, Trochodendron aralioides* and *Alnus* increase, suggesting the development of poorly vegetated and unstable mountain slopes.

Pollen zone III: The beginning of this zone corresponds to the development of the New Peat, about 2,500 years B.P. *Symplocos, Rhododendron* and *Alnus* pollen values decrease, while *Cryptomeria* and *Trochodendron aralioides* increase upward, suggesting the development of the *Cryptomeria* forest with *Trochodendron aralioides*. The mountain slopes surrounding the Hananoego moor became covered by the *Cryptomeria* forest and a stable sedimentary environment appeared. In the top of the pollen diagram, *Artemisia, Plantago* and charcoal increase, indicating human interference with the vegetation.

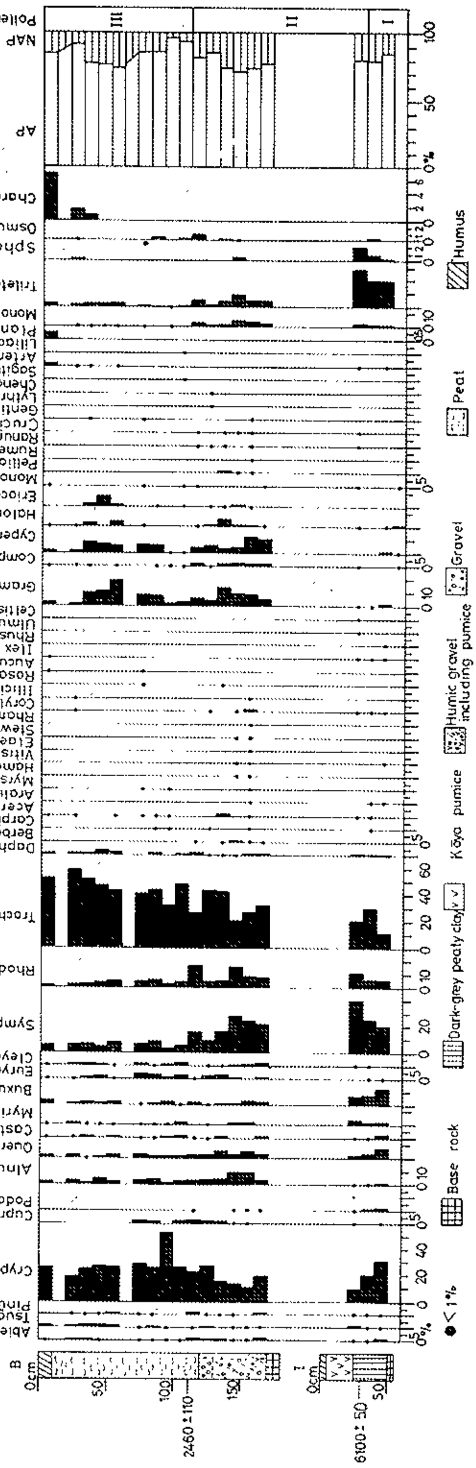

Fig.4. Pollen diagram from the Hananoego moor. Values expressed as percentages of total tree pollen.

DISCUSSION

The results of the pollen analysis of the old Hananoego moor showed high frequency values of *Castanopsis, Quercus Cyclobalanopsis* and *Podocarpus*, which presently grow at an altitude lower than 1,200m.

The Kikai caldera volcano which was located 50km northwest of Yakushima erupted 6,300 years B.P. This vast eruption began with the fall of the Kōya pumice and then small pyroclastic flow, and was followed by the vast Kōya pyroclastic flow and the Akahoya volcanic ash fall (Fig. 5) (Machida, 1986). The Kōya pyroclastic flow even crossed the sea and reached Yakushima (Fig. 5). Yakushima was densely covered by the Kōya pyroclastic flow deposit. The influences of these volcanic

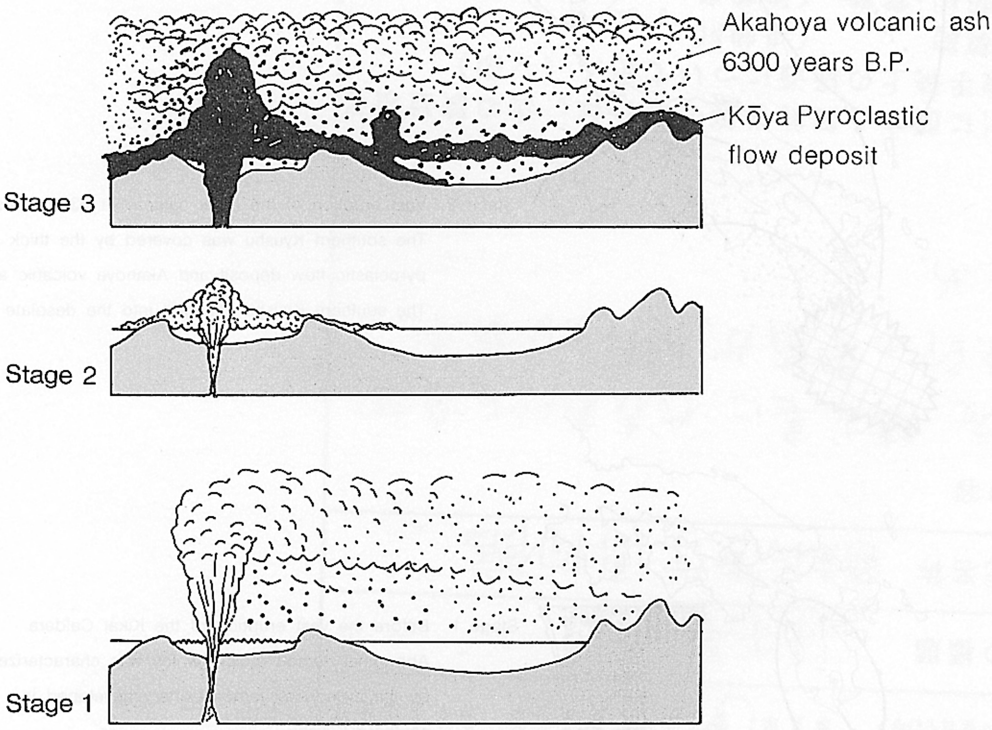

Fig.5. Model of the vast eruption of the Kikai caldera around 6,300 years B.P. (after Machida and Kojima, 1986).
Stage 3: Vast eruption of the Kōya pyroclastic flow deposit and Akahoya volcanic ash. The Kōya pyroclastic flow crossed the sea and reached Yakushima.
Stage 2: Eruption of small pyroclastic flow deposit.
Stage 1: Eruption of pumice and volcanic ash.

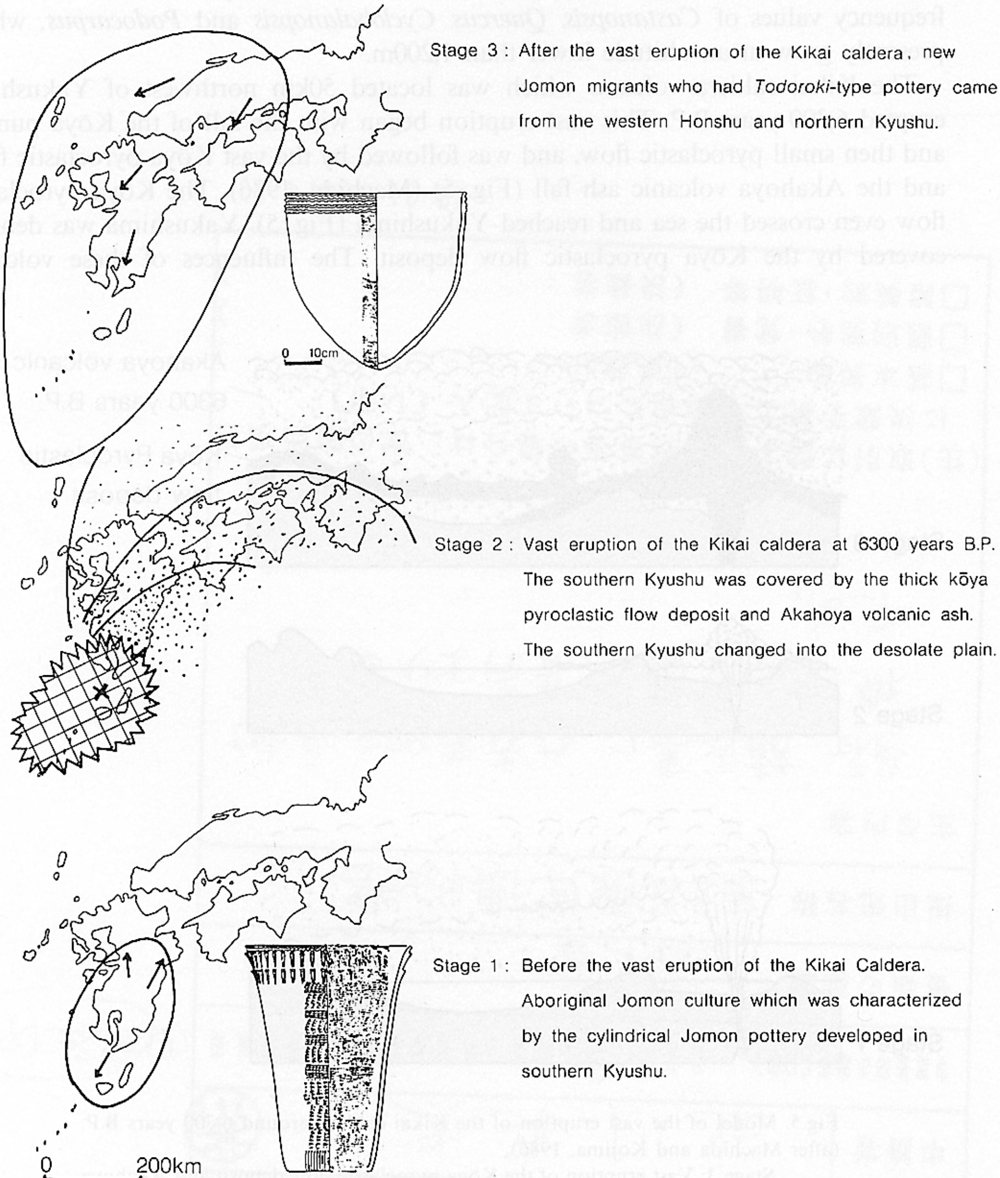

Fig.6. Schematic map of the influences of vast eruption of the Kikai caldera on the Jomon culture (after Machida, 1984).

eruptions on the vegetational history of Yakushima find expression also in the results of palynological studies.

Pollen analysis of the Hananoego moor shows that *Cryptomeria, Buxus, Quercus Cyclobalanopsis, Podocarpus* and *Castanoposis* decrease in the pollen zone II, while *Symplocos, Rhododendron* and *Trochodendron aralioides* increase, suggesting the recession of dense *Cryptomeria* forest and the expansion of open land under the influence of the initial fall of the ash and pumice. Finally, the Kōya pyroclastic flow covered Yakushima even at the summit of Mt. Miyanoura. We could not discover any remains of pollen from the Kōya pyroclastic flow deposit.

It can be said that forest mainly composed of *Cryptomeria japonica, Quercus Cyclobalanopsis, Buxus, Symplocos, Rhododendron* and *Trochodendron aralioides* surrounding the Hananoego moor sustained great damage. The destruction of the forest by the Kōya pyroclastic flow occurred all over Yakushima. It is surmised that the giant Japanese cedar (*Yakusugi*) was largely destroyed by this vast eruption. We indentify this extinct *Yakusugi* as *Old Yakusugi*.

This vast eruption of the Kikai caldera volcano also caused the dramatic ruin of the Jomon culture in the Kyushu district. Early Jomon potteries found directly under the Akahoya volcanic ash layer are characterized by *Senokan-type* pottery which has a cylindrical form and a strong aboriginality (Fig. 6). After the fall of the Akahoya volcanic ash layer, *Senokan-type* pottery disappeared and new types of pottery named *Todoroki-type* pottery appeared, suggesting extensive cultural ruin and the arrival of new migrants (Fig. 6). Archeologist Shintō (1988) surmised that the society of the early Jomon people who made the *Senokan-type* potteries was severely damaged by the effects of the eruption of the Kikai caldera volcano.

After the deposition of the Kōya pyroclastic flow, barren mountain slopes appeared in Yakushima which were subject to severe erosion by the heavy rains of this island. The cross section of the Hananoego moor shows the development of a gravel bed older than 2,500 years B.P. This gravel bed includes redeposited Kōya pumice and shows high concentrations of *Symplocos, Rhododendron, Trochodendron aralioides* and *Alnus*, suggesting the unstable sedimentary environment and frequent occurrence of land slides.

After 2,500 years B.P. highly humified peat developed and the New Hananoego moor appeared. *Cryptomeria* shows high values, indicating the development of giant Japanese cedar forest surrounding the Hananoego moor. We call this new giant Japanese cedar *New Yakusugi*. Results of pollen analysis from other sites in the Japanese archipelago (Yasuda, 1978, 1990) suggest a climatic deterioration occurring around 2,500 years B.P. It is suggested that this climatic deterioration in the late Holocene period gave rise to the development of the New Hananoego moor.

This vegetational history of the Hananoego moor area is summarized in Fig. 7 by the changes in the schematic landscape.

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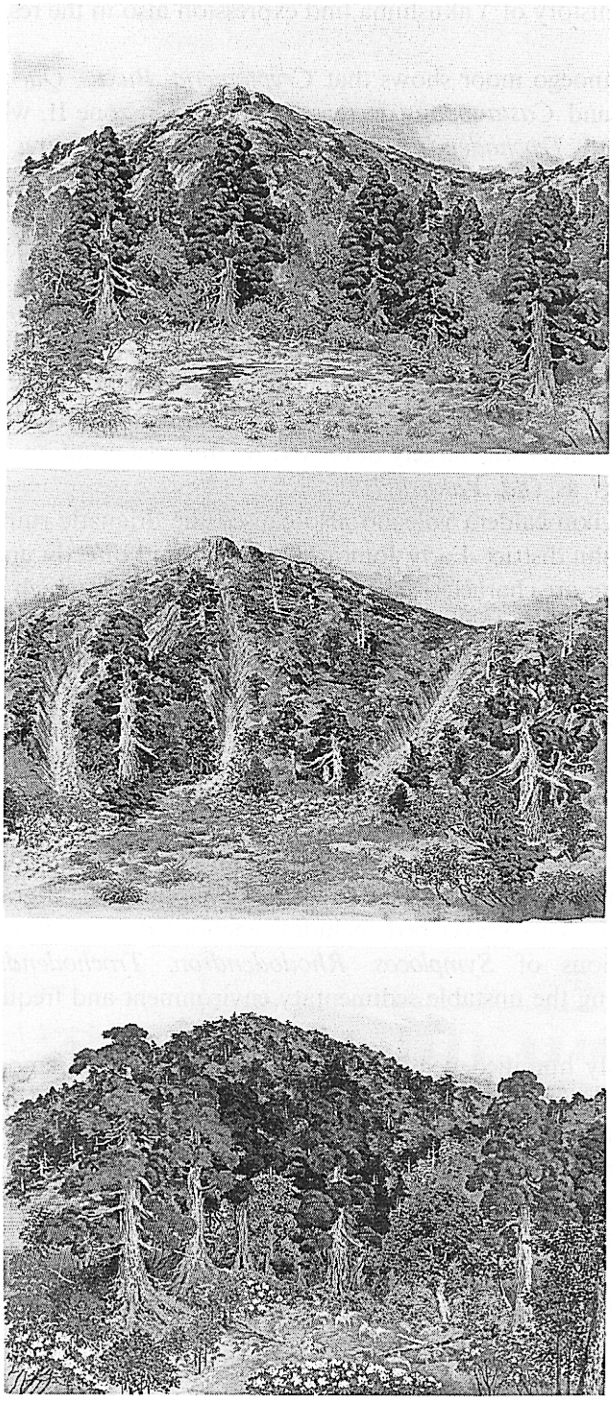

2500 years B.P.
New Hananoego Moor
and *New Yakusugi*

5500 years B.P.
Old Yakusugi were
killed by the Kōya
Pyroclastic flow deposit
at 6300 years B.P. and
after that time
unstable sedimentary
environment appeared.

6500 years B.P.
Old Hananoego Moor
and *Old Yakusugi*

Fig.7. Schematic landscape map of the Hananoego moor (pictured by Amagi).

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鬼界カルデラの噴火が屋久島の完新世の植生変遷史に及ぼした影響について

安田喜憲

要旨：屋久島の花之江河湿原の花粉分析の結果、6300年前に噴火した鬼界カルデラによる幸屋火砕流堆積物によって、古屋久杉やヤマグルマからなる古花之江河湿原周辺の森林は壊滅的打撃を被ったことが、明らかとなった。現在の新花之江河湿原は約2500年前に形成された。

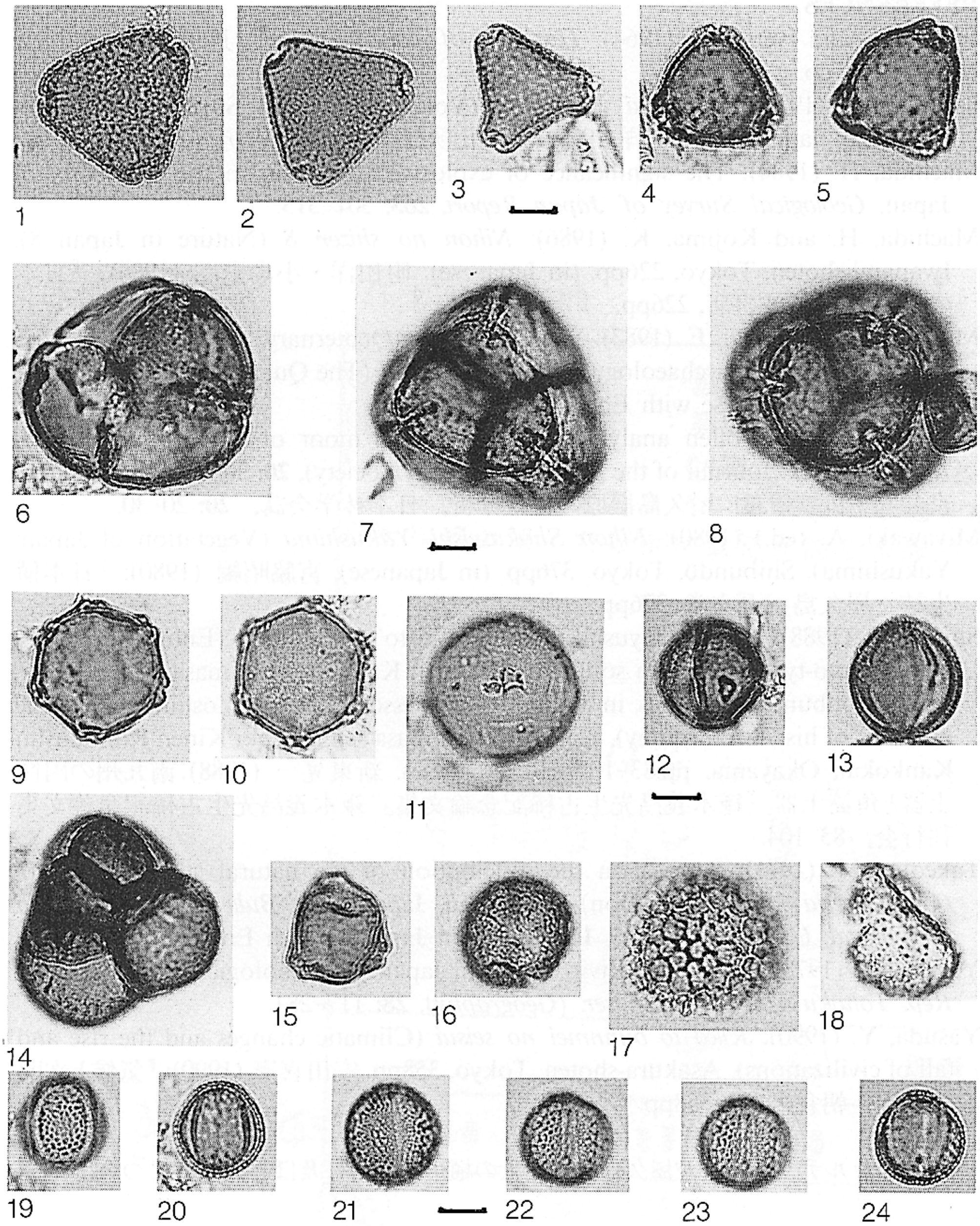

Plate 3 Fossil pollen found in the Hananoego moor.
1–5. *Symplocos* 6–8. *Rhododendron*
9 and 10. *Alnus* 11. *Cryptomeria* 12. *Quercus Cyclobalanopsis*
13. *Acer* 14. *Rhododendron* 15. *Myrica* 16. *Buxus*
17. *Lycopodium* 18. *Eriocaulon* 19–24. *Trochodendron aralioides*
Bar is 10μ.

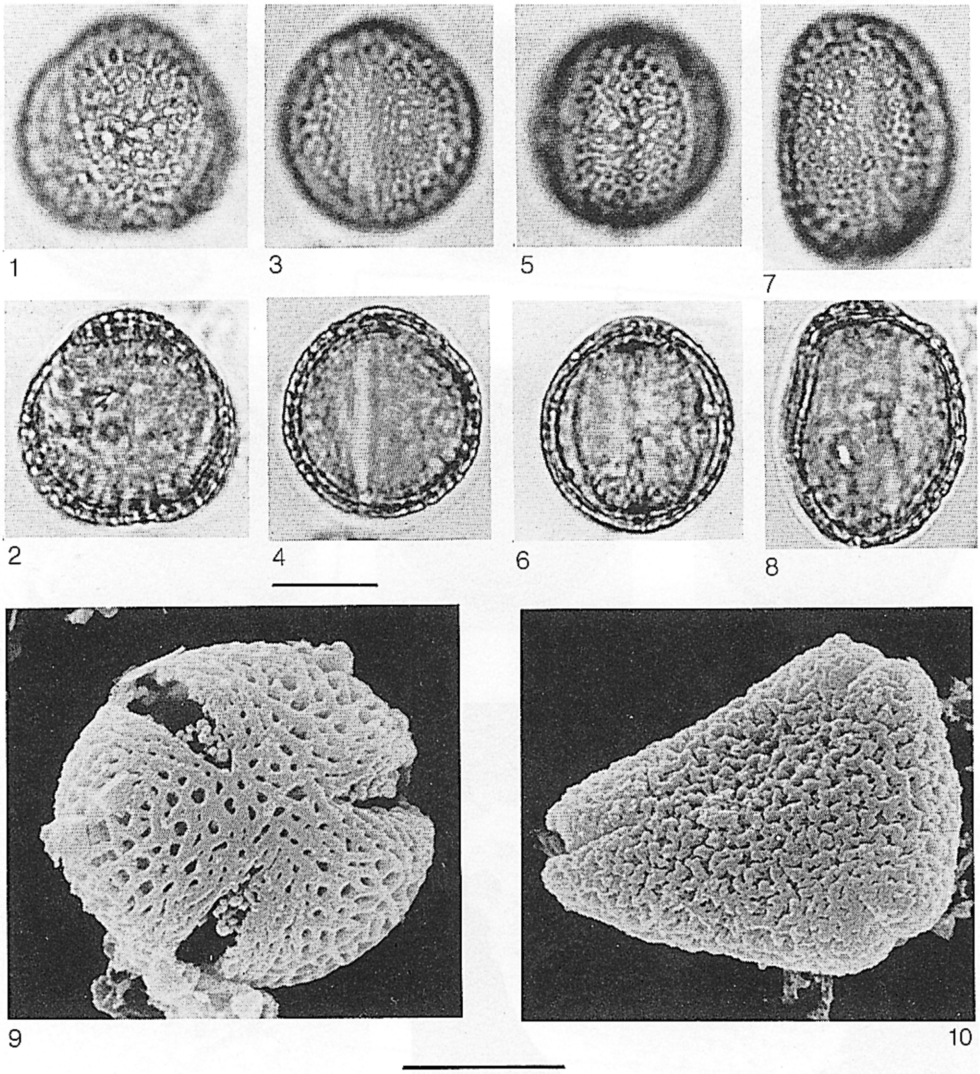

Plate 4 Fossil pollen of *Trochodendron aralioides* and *Symplocos* found in the Hananoego moor.

1–9. *Trochodendron aralioides.*
1. Ornamentation in equatorial view in high focus (LM).
2. Optical cross-section in equatorial view (LM).
3. Colpus in equatorial view (LM).
4. Optical cross-section in equatorial view (LM).
5. Ornamentation in equatorial view in high focus (LM).
6. Optical cross-section in equatorial view (LM).
7. Ornamentation and colpus in equatorial view (LM).
8. Optical cross-section in equatorial view (LM).
9. Ornamentation in polar view (SEM).
10. *Symplocos*(SEM).

Bar is 10μ

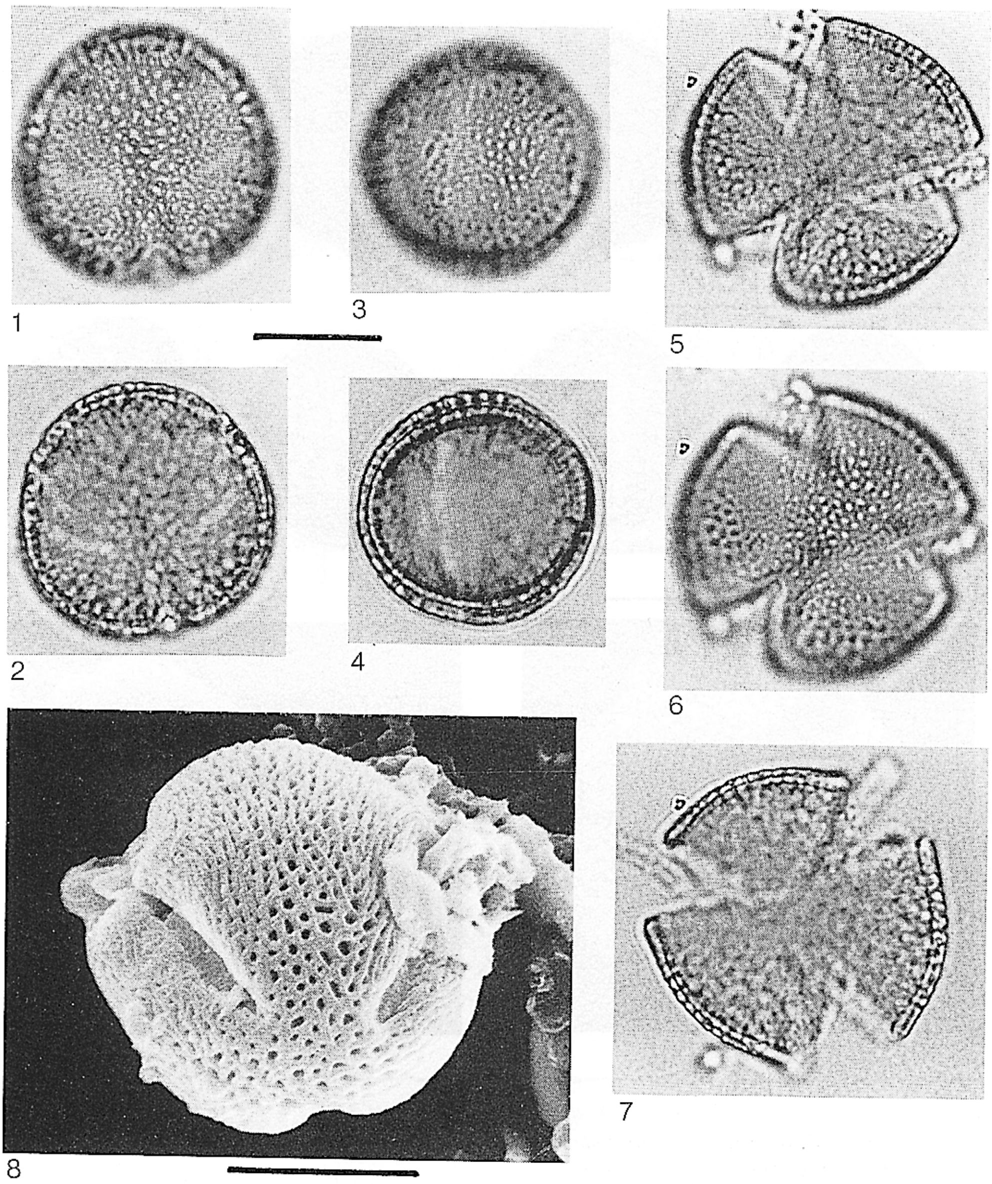

Plate 5 Recent pollen of *Trochodendron aralioides*.

1. Ornamentation in polar view in high focus (LM).
2. Cross-section in polar view (LM).
3. Colpus in equatorial view (LM).
4. Cross-section in equatorial view (LM).
5. Ornamentation in polar view in middle focus (LM).
6. Ornamentation in polar view in high focus (LM).
7. Cross-section in polar view (LM).
8. Ornamentation in equatorial view (SEM).

Bar is 10μ.