5.2–5.8 ka BP PALEOENVIRONMENT OF THE SOUTHERN SLOPE OF MOUNT RAIZAN, JAPAN

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ABSTRACT. Accelerator mass spectrometry (AMS) radiocarbon dating and paleoecological analysis of slope deposits at Mt Raizan provided seven ^{14}C dates indicating that landslides occurred in that area at 6.0 to 6.3 cal ka BP and 6.5 cal ka BP. Plant macrofossils, pollen grains, and spores point to a mixed forest at that time, consisting of conifers and broad-leaved trees. On the other hand, insect fossil indicates slightly colder climate than that of the flora. This difference may be attributed to varied sensitivities of each proxy to climatic changes.

INTRODUCTION

In March 1997 a wood trunk was excavated from a construction site (500 m asl; 32°27'42"N, 130°12'40"E) along the mountain trail in the southern slope of Mt Raizan (955 m asl) located in the northern part of Kyushu Island, southwest Japan (Figure 1). The wood was identified as *Torreya nucifera* Sieb. et Zucc. and dated to 5290 ± 110 BP (NUTA-5640), based on the outermost 2–3 tree-rings (Nagaoka et al. 1998; Okuno et al. 2001).

Mt Raizan is one of the most prominent peaks in the Seburi Mountains and composed mainly of Paleozoic Sangun Metamorphic Rocks and Cretaceous Itoshima Granodiorite (Karakida 1992).

In order to reconstruct the paleoenvironment of this mountainous area, the adjoining sites (sections A and B) were excavated on March and July of 1999 and a thorough investigation was made. This paper presents the results of accelerator mass spectrometry radiocarbon dating as well as paleoecological analysis.

SAMPLES AND ANALYTICAL METHODS

Stratigraphy

Figure 2 shows the stratigraphic relations of the slope deposits at sections A and B (Figure 1). These deposits unconformably overlie the Itoshima Granodiorite and are divided into five units: clay layer 1 (Cl-1), gravel layer 1 (Gl-1), clay layer 2 (Cl-2), gravel layer 2 (Gl-2), and surface soil in ascending order. The clay layers occur as blue-gray materials with fine-grained matrix, include some wood trunk remains and aggregates of metamorphic gravel. These layers are regarded as landslide in origin. On the other hand, the gravel layers are brown, clast-supported conglomerates that probably derive from debris flows.

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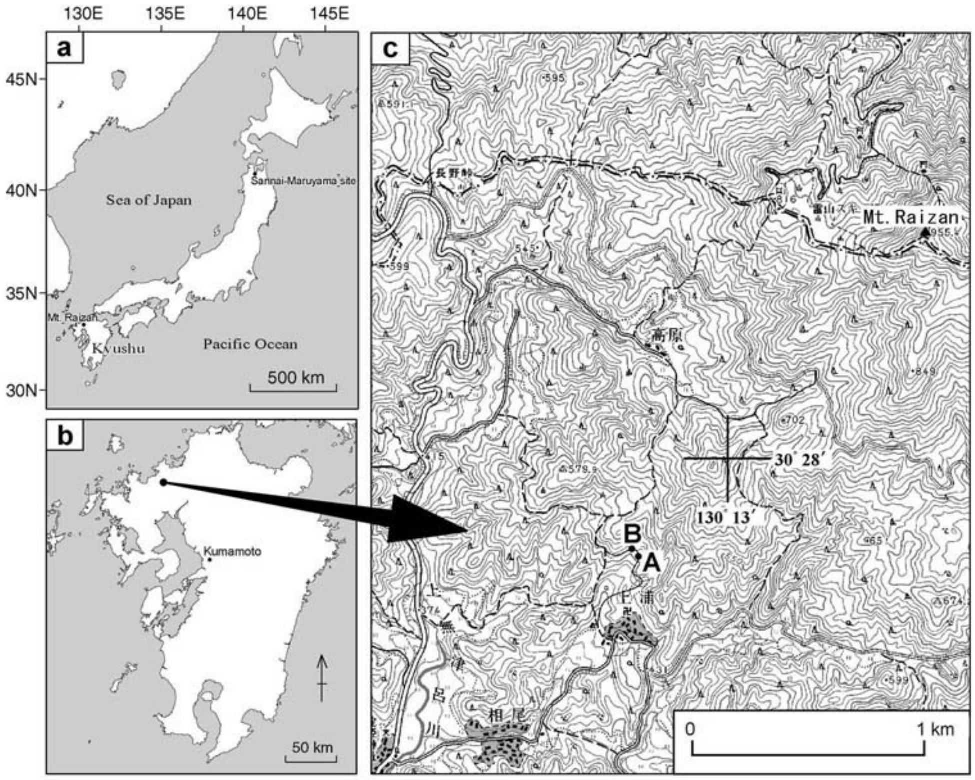

Figure 1 Index and location maps: a) map showing the locations of Kyushu Island and Sannai-Maruyama archaeological site, b) location map of Mt Raizan and Kumamoto Plain, and c) localities of excavation sites (sections A and B) on the 1:25,000 scale topographic map of “Raizan” published from Geographical Survey Institute (Japan)

Paleoecological Analysis

A total of 16 specimens of wood trunks from two clay layers of sections A and B were obtained. Sediment samples including biological evidences such as macrofossils, pollen, and insect remains, were also collected from both sections (Figure 2). Three-directional, i.e. (longitudinal) transverse, radial, and tangential hand-sections of the wood specimens were obtained using a razor blade and later mounted with Gum-chloral. The anatomical characteristics were observed with a binocular microscope.

Many fruits, seeds, and leaves were obtained by sieving the sediment sample A-4. The residue was examined under a microscope and identifiable fossils were picked up. All specimens were preserved in 50% alcohol.

For pollen analysis eight sediment samples (A-1 to -4, B-1 to -4) were prepared utilizing the HF-KOH-acetorysis method (Nakamura 1975). The obtained pollen and spore grains were then observed under a microscope with a magnification of 600 times. We counted a preliminary 100–200 grains of arboreal pollen with aberrant two samples counted at less than 60 grains.

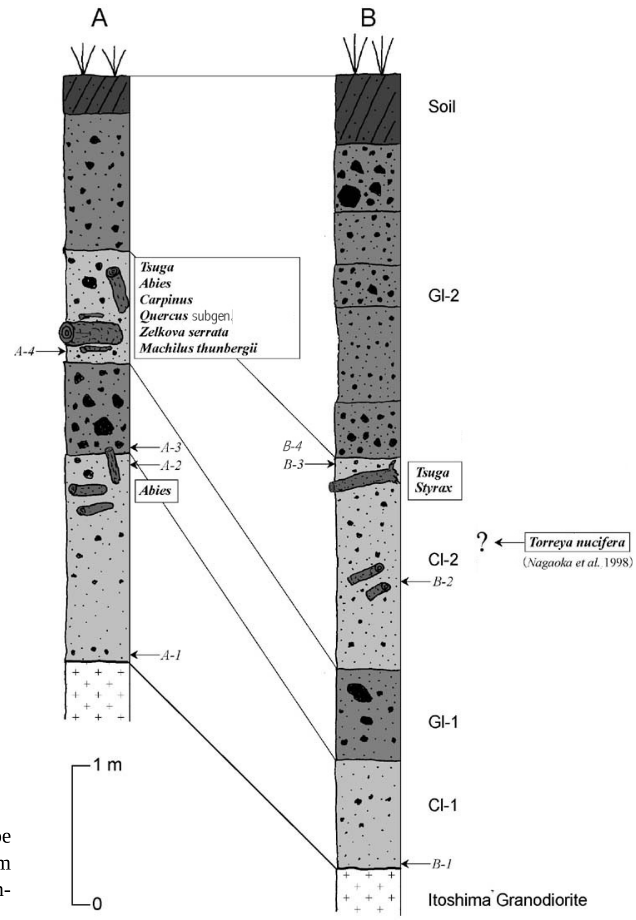

Figure 2 Stratigraphic relations of slope deposits at sections A and B (modified from Okuno et al. 2001). Arrows indicate sampling horizons.

The fossil insect remains were retrieved from samples A-4 and B-3 using both lamina cutting and water separation methods. Identification of the insect fossils was accomplished by comparison of each remains with modern insect specimens under a microscope.

AMS ^{14}C Dating

A total of six wood and one stone fragments were ^{14}C-dated (Table 1). The outermost 2–3 tree rings of wood samples were cut into small chips. These samples were washed with distilled water and then cleaned chemically by acid-alkali-acid (AAA) treatments. The treated samples were sealed in an evacuated Vycor® tube with CuO, and combusted at 850 °C in an electric furnace. The resulting CO_2 was purified cryogenically in a vacuum line and then reduced catalytically to graphite on Fe-powder with H_2 in a sealed Vycor tube (Kitagawa et al. 1993). Measurement of ^{14}C /^{13}C ratio of a graphite target was carried out using either a GIC Tandetron AMS (Nakamura et al. 1987) or an HVEE Tandetron AMS (Nakamura et al. 2000) at Nagoya University. We used NIST HoxI or HoxII as standards. The carbon isotopic fractionation was corrected by δ^{13}C, measured on a Finnigan MAT 252 mass spectrometer.

Table 1 AMS ^{14}C dates of woods and stone fragments from the Cl-1 and Cl-2

Locality	Stratigraphic position	Material (specific name)	$\delta^{13}C$ (‰)	^{14}C date (BP)	Cal range BP (1σ) probability (%)	Measurement code
A	Clay layer 2	Wood (*Quercus* subgen. *Cyclobalanopsis*)	–29.9	5310 ± 100	6196–5985 (92.5) 5969–5950 (7.5)	NUTA–6313
A	Clay layer 2	Wood (*Tsuga*)	–28.1	5220 ± 100	6171–6140 (11.3) 6106–5896 (88.7)	NUTA–6314
A	Clay layer 2	Wood (*Tsuga*)	–27.9	5410 ± 25	6273 –6229 (70.1) 6214–6195 (29.9)	NUTA2–762
B	Clay layer 2?	Wood (*Torreya nucifera*)	–25.9	5290 ± 110	6176–5938 (100)	NUTA–5640
B	Clay layer 2	Wood (*Styrax*)	–29.0	5560 ± 25	6397–6369 (44.1) 6344–6322 (32.9) 6319–6305 (23.0)	NUTA2–758
B	Clay layer 2	Stone (*Styrax*)	–28.4	5565 ± 25	6398–6369 (44.6) 6345–6309 (55.4)	NUTA2–759
A	Clay layer 1	Wood (*Abies*)	–27.7	5800 ± 25	6662–6620 (48.1) 6608–6559 (51.9)	NUTA2–763

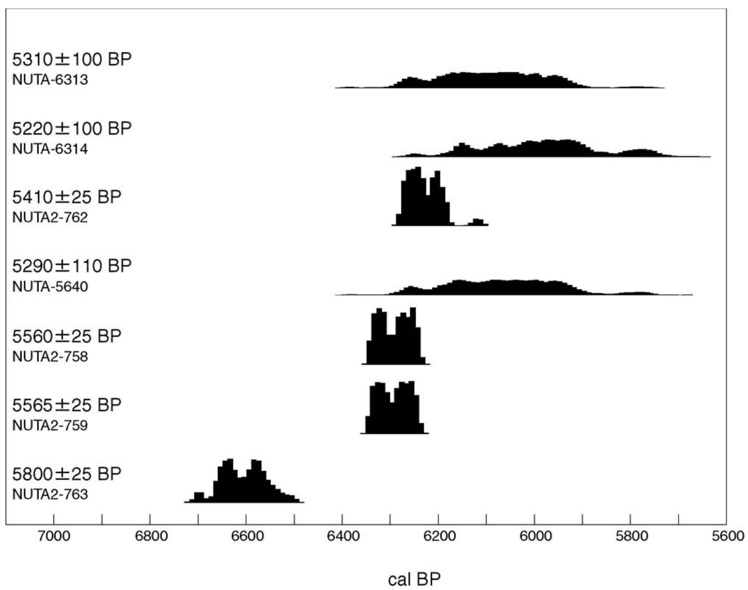

Figure 3 Calibration probability plots of AMS ^{14}C dates. Based on dendrochronological data (Stuiver and Pearson 1993) using the Calib ETH 1.5b program (Niklaus et al. 1992)

RESULTS AND DISCUSSION

Seven AMS ^{14}C dates ranging from about 5.2 to 5.8 ka BP (Table 1) are calibrated to calendar years based on dendrochronological data (Stuiver and Pearson 1993) using the Calib ETH 1.5b program (Niklaus et al. 1992). The calibrated year range can be divided into two groups (Figure 3) that are almost consistent with the stratigraphy. These dates indicate that landslide have occurred at least two times (6.0 to 6.3 cal ka BP and 6.5 cal ka BP) in the middle Holocene.

Eight taxa—*Abies*, *Tsuga*, *Torreya nucifera*, *Carpinus*, *Quercus* subgen., *Cyclobalanopsis*, *Zelkova serrata*, *Machilus thunbergii,* and *Styrax*—were identified through anatomical characteristics (Figure 2). Only one taxon, *Abies*, was obtained from the Cl-1. On the other hand, all taxa were obtained from the Cl-2. These fossils show the formation of *Abies-Tsuga* and evergreen oak forests in this period. Bark and last annual ring tissues were observed in three specimens (Figure 4). These indicate the season of their death as well as an occurrence of landslide.

In sample A-4 the macrofossils were composed of nine taxa including seven families, eight genera, and four species. Two taxa of gymnosperms, six of woody angiosperms and one of herbaceous angiosperms, were recognized. They were identified as *Abies*, *Tsuga*, *Quercus* subgen., *Cyclobalanopsis*, *Mallotus japonicus*, *Vitis*, *Fagara ailanthoides*, *Phellodendron amurense*, *Cornus macrophylla*, and *Chenopodiaceae*. The typical fossils were evergreen coniferous trees such as *Abies* and *Tsuga*, evergreen broad-leaved trees such as *Quercus* subgen. *Cyclobalanopsis*, warm temperate deciduous trees such as *Mallotus japonicus*. In the course of pollen analysis, stone fragments of *Styrax* were also obtained from sample B-3.

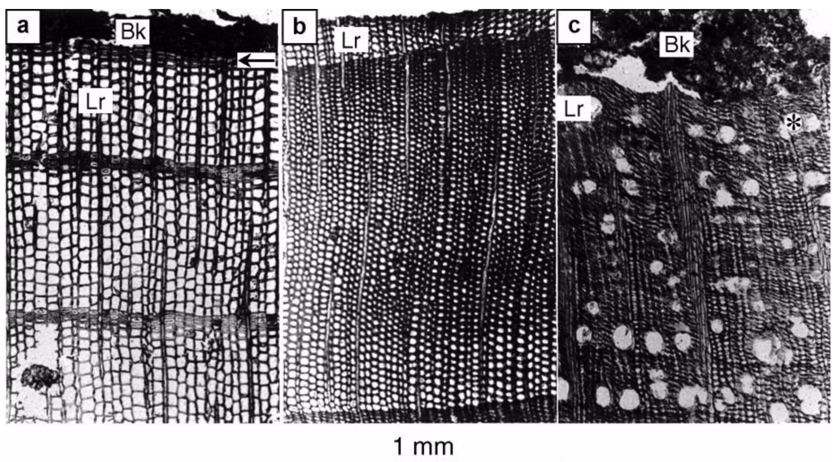

Figure 4 Thin sections of wood trunks (from Okuno et al. 2001): a) *Abies* from the Cl-1 of section A, died in summer (maybe before mid-summer), b) *Tsuga* from the Cl-2 of section A, died in early spring, and c) *Styrax* from the Cl-2 of section B, died in spring. Bk: bark, Lr: last annual ring, *: pores of last annual ring.

All samples excluding samples A-1, A-3 and B-1 showed a similar pollen composition. In conifers, *Abies* pollen usually occurs with high percentage, accompanied by *Podocarpus*, *Pinus*, and *Tsuga*. In broad-leaved tree pollen, *Quercus* subgen. *Lepidobalanus* has also a high percentage, accompanied by *Quercus* subgen. *Cyclobalanopsis*, *Ulmus* and/or *Zelkova*, *Castanea* and/or *Castanopsis* and *Carpinus*. *Fagus*, *Elaeagnus*, *Myrica*, *Cornus*, and *Mallotus* have rather low percentages. The composition of pollen taxa originating from forests of temperate broad-leaved trees with conifers includes *Abies* and *Podocarpus*. The vegetation in this period shows evidence of a mixed forest consisting of conifers and broad-leaved trees mentioned above. This implies a transitional forest zone between cool-temperate and warm-temperate zones. In the undergrowth, fern was luxuriant, accompanied by grasses such as Umbelliferae and *Artemisia*. The composition and frequency of the pollen flora in the site correlates with the RIIIa pollen zone defined by Tsukada (1963, 1967). Iwauchi and Hase (1992) clarified the climatic changes based on the pollen record of the Kumamoto Plain. The vegetation on the sites of the slope of Mt Raizan, however, differs from the composition of the RII and RIIIa as shown by Iwauchi and Hase (1992). Hatanaka et al. (1998) mentioned that the pollen composition at the RIIIa in the lowland of Kyushu Island was composed of warm-temperate elements similar to those of the climatic optimum of the Holocene. It is, therefore, suggested that the vegetation had a more cool-temperate composition than the RII and RIIIa vegetation on the lowland in Kyushu, because the site is at 500 m elevation, which is higher than that indicated by Iwauchi and Hase (1992).

Table 2 Fossil insect remains from samples A-4 and B-3

Family and order	Lower taxon	Ecology	Food habit	A-4	B-3	Sum
Hydrophilidae	*Coelostoma orbiculare* (Fabricius)	Aquatic	Phytophagous	E1		1
Carabidae	Platynini	Geophilous	Carnivorous	P3 E1		4
	Synuchus sp.	Geophilous	Carnivorous	E5	P1	5
	Bembidion sp.	Geophilous	Omnivorous	P1		1
Staphylinidae	unidentified	Geophilous	Omnivorous	P6 E10 H4 A2 B2		25
	unidentified	Geophilous	Omnivorous	P1 E2	E1	4
Tenebrionidae	*Plesiophthalmus* sp.	Geophilous	Phytophagous	E2		2
	unidentified	Geophilous	Omnivorous	E2		2
Scarabaeidae	*Onthophagus* sp.	Geophilous	Coprophagous	A1		1
	Mimela takemurai (Sawada)	Terrestrial	Phytophagous	P2	E1	3
	unidentified	Terrestrial	Phytophagous	P2		2
Chrysomelidae	unidentified	Terrestrial	Phytophagous	E2		2
Curculionidae	unidentified	Terrestrial	Phytophagous	B1	E1	2
Elateridae	*Melanotus erythropygus* (Canteze)	Terrestrial	Omnivorous	P1		1
	unidentified	Terrestrial	Omnivorous	E2		2
Synchroidae	*Synchroa melanotoides* (Lewis)	Terrestrial	Phytophagous	E2 P1		3
Scolytidae	*Crossotarsus simplex* (Murayama)	Terrestrial	Phytophagous	E2		2
	unidentified	Terrestrial	Phytophagous	P1		1
Formicidae	unidentified	Terrestrial	Omnivorous	H4		4
Diptera	unidentified	Terrestrial	Omnivorous	O4		4
Unidentified insects		Unknown	Unknown	E10 B2 A1 O7		20
Total				87	4	91

A-4 and B-3: see figure 2, E: elytron, H: head, P: pronotum, A: abdomen, B:breast, O: others.

Ninety-one fossil insect remains corresponding to 11 families and one order were identified (Table 2 above). These insect fossils were characterized by many ground-wandering beetles and some various terrestrial phytophagous beetles. Ground-wandering beetles include species mostly living on the wetland surrounded by a forest, such as Platynini, *Synuchus* species, other Carabidae, Staphylinidae, and *Plesiophthalmus* species. Phytophagous beetles are composed of forest species such as *Mimela takemurai*, Chrysomelidae, Curculionidae, and *Crossotarsus simplex*. The assemblage of the fossil insects suggests a woody land mixed with deciduous broad-leaved trees and coniferous trees. It is assumed that the climate at that time was slightly colder than at the present, judging from the presence of northern species such as *Coelostoma orbiculare*, *Synchroa melanotoides*. These species were also found from the Sannai-Maruyama archaeological site (10 m asl, about 5 ka BP), northeastern Japan (Mori 1999, Figure 1a). The assemblage of fossil insects indicates slight-cold climate than that of the flora mentioned above.

The difference of paleoclimate inferred from plant and insect fossils in the sites is discussed as follows. At 5.7 ka BP, the pollen record of the Kumamoto Plain indicates warm-temperate environment, but the ratio of evergreen oak pollen is slightly decreased (Iwauchi and Hase 1992). It implies that the environment in Kyushu Island changed from climatic optimum to cool in the short term. In this case, not only pollen that is slow in response, but also insect data that responds to short and abrupt climatic changes are useful for interpretation (Guoit et al. 1993; Ponel 1995). The southern slope of Mt Raizan at 5.2–5.8 ka BP was under a cool-temperate environment as suggested by insect data, as well as a transitional environment from warm- to cool- temperate suggested by pollen analysis.

CONCLUSION

We studied the paleoenvironment in the middle Holocene of mountainous sites (500 m asl) in Kyushu Island, Japan.

1. AMS ^{14}C dates of one stone and six wood fragments are consistent with the stratigraphy of the area and indicate that landslides occurred at least twice (6.0 to 6.3 cal ka BP and 6.5 cal ka BP) during that time.
2. Plant macrofossils, pollen grains, and spores indicate a mixed forest consisting of conifers and broad-leaved trees at that time. The vegetation consisted of a cooler composition than the RII or RIIIa vegetation on the lowland in Kyushu Island.
3. Fossil insect remains indicate a slightly colder climate than that of the flora. The difference may be attributed to varied sensitivities of each proxy to climatic changes.

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