Jpn. J. Histor. Bot. Vol. 17 No. 2 p. 45–53 September 2009 植生史研究

Original article

Masami Watanabe[1], Takeshi Furuno[1, 2] and Takayoshi Nasu[3]:

Paleovegetation at the Sanbe-Azukihara *Cryptomeria japonica* buried forest and its vicinity at ca. 3500 yrs BP, Shimane Prefecture, southwestern Japan

渡辺正巳[1]・古野　毅[1, 2]・那須孝悌[3]：

島根県中央部, 三瓶小豆原スギ埋没林とその周辺におけるおよそ3500年前の古植生

Abstract Identification of buried woods and pollen analysis were carried out to reveal the paleovegetation of the Sanbe-Azukihara buried forest in Shimane, southwestern Japan. The buried forest was formed by a debris avalanche derived from Mt. Sanbe at ca. 3500 yrs BP. The paleoflora in the Sanbe-Azukihara buried forest was mainly composed of *Cryptomeria japonica*, *Chamaecyparis obtusa*, *Cephalotaxus harringtonia*, cf. *Castanopsis cuspidata*, *Quercus* subgen. *Cyclobalanopsis* sp., *Zelkova serrata*, *Aesculus turbinata*, *Cercidiphyllum* sp., and *Sapindus mukorossi*. The study results indicated that vegetation changed gradually from a wasteland to a *Cryptomeria japonica* forest through a riparian forest between 4500 and 3500 yrs BP. In central Chugoku region where the study area is located, the high ratio of *C. japonica* pollen has not so far been reported from pollen analytical studies through the Holocene. The discovery of a buried forest of *Cryptomeria japonica* in the central Chugoku region shows that this area had a cool humid climate suitable for the growth of *C. japonica* and provides a material to clarify the reason for the weak development of *C. japonica* forests during the Holocene in this region.

Keywords: *Cryptomeria japonica*, paleovegetation, pollen analysis, Sanbe-Azukihara buried forest, species identification of buried trees

要　旨　三瓶小豆原埋没林は西南日本の島根県に位置し，およそ3500年前の三瓶山の火山活動によって形成された。三瓶小豆原埋没林において樹種同定と花粉分析を実施して，古植生を明らかにした。30試料の埋没立木と火山泥流に含まれていた33試料の埋没流木の樹種同定の結果，9分類が識別され，三瓶小豆原埋没林の植物相がスギ，ヒノキ，イヌガヤ属，ツブラジイ類似，コナラ属アカガシ亜属，ケヤキ，トチノキ，カツラ属，ムクロジなどからなることが分かった。花粉分析の結果，2花粉帯4花粉亜帯を設定した。これらのことから，およそ4500年前から3500年前の間に，荒れ地から河畔林を経てスギ林へと植生が変遷したことが分かった。 また本地域は，完新世の花粉分析で今までスギ花粉の高率出現が報告されていない，中国地方中央部に位置する。本地域でおよそ3500年前頃の埋没スギ林が発見されたことにより，本地域がスギの生育に適した冷涼多雨の気候であったことが分かった。さらに，今回の発見は，中国地方中央部で完新世においてスギ林が発達しにくかった原因について論じる上で，貴重な資料となる。

キーワード：花粉分析，古植生，三瓶小豆原埋没林，樹種同定，スギ

Introduction

The central Chugoku region has been recognized as an area with scarce natural distribution of *Cryptomeria japonica* through the Holocene (Takahara et al., 1997; Takahara, 1998). The Sanbe-Azukihara buried forest, a rare example of a Holocene *Cryptomeria japonica* forest in this region, was formed by a series of volcanic activities of Mt. Sanbe. The volcanic activities of Mt. Sanbe between 100,000 and 500 yrs BP are divided into eight active stages from Sanbe volcano I to VIII (Fukuoka & Matsui, 2004). The Sanbe-Azukihara buried forest was formed by volcanic activities in the Sanbe volcano stage VII (Nakamura, 2003). We investigated the taxa and distribution of the buried trees

---

[1] Archaeological Research Consultant, Inc., 131 Shimohigashikawatsu, Matsue, Shimane 690-0822, Japan
〒690-0822　島根県松江市下東川津町131　文化財調査コンサルタント株式会社

[2] Faculty of Science and Engineering, Shimane University, 1060 Nishikawatsu, Matsue, Shimane 690-8504, Japan
〒690-8504　島根県松江市西川津町1060　島根大学総合理工学部

[3] Deceased. Osaka Museum of Natural History, 1-23 Nagai Park, Higashi-Sumiyoshi-ku, Osaka 546-0034, Japan
故人．〒546-0034　大阪市東住吉区長居公園1-23　大阪市立自然史博物館

and carried out pollen analysis of the sediment in the Sanbe-Azukihara buried forest to clarify the paleovegetation at the Azukihara and its vicinity at ca. 3500 yrs BP and the changes in vegetation from ca. 4500 to 3500 yrs BP. Results of our study on the Sanbe-Azukihara buried forest indicated the environmental conditions that define the distribution of *C. japonica* forests during the Holocene in this region.

Description of study site

The Sanbe-Azukihara buried forest is situated at the northern foot of Mt. Sanbe in the central Chugoku region, southwestern Japan, about 10 km from the sea (Fig. 1). The Sanbe-Azukihara buried forest was formed by the volcanic activities of the Sanbe-volcano stage VII (Fig. 2). Radiocarbon ages for the Sanbe volcano stage VII range from 3790 ± 35 to 3316 ± 40 yrs BP, those for paleosoil (Second Black Soil) directly covered by the sediments of the Sanbe volcano stage VII from 4850 ± 40 to 3600 ± 40 yrs BP, and those for the Sanbe volcano stage VI from 4850 ± 70 to 4480 ± 110 yrs BP (Fukuoka & Matsui, 2004). In the Sanbe-volcano stage VII a debris avalanche covered a giant *C. japonica* forest at ca. 3500 yrs BP and brought huge driftwoods to the Azukihara area. The deposits dammed up the Azukihara River and formed a natural dam lake. Subsequent pyroclastic flow and volcanic ash flowed into the lake and filled it up, burying the trees more deeply.

Species identification of the buried forest and pollen analysis of the buried paleosoil were conducted in the Large Exhibition Room of the Sanbe-Azukihara Buried Forest Park and its vicinity (Fig. 3). The buried forest occurs in a basin, ca. 1 km in diameter at ca. 220 m alt., along the Azukihara River, a branch of the Sanbe River flowing from Mt. Sanbe. The basin is surrounded by ridges about 300 m alt. According to the actual vegetation maps (Environment Agency, 1982, 1986), the surrounding areas are covered with compensation

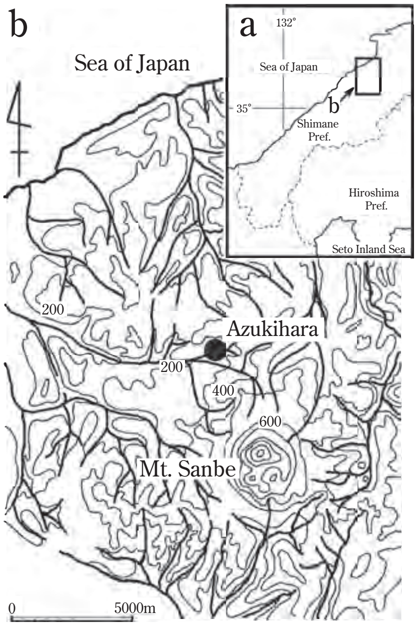

Fig. 1 Location of the study site. — a: Map of the Sanbe district. b: Location of the Azukihara area, the contour topography, and the river system in the Sanbe district.

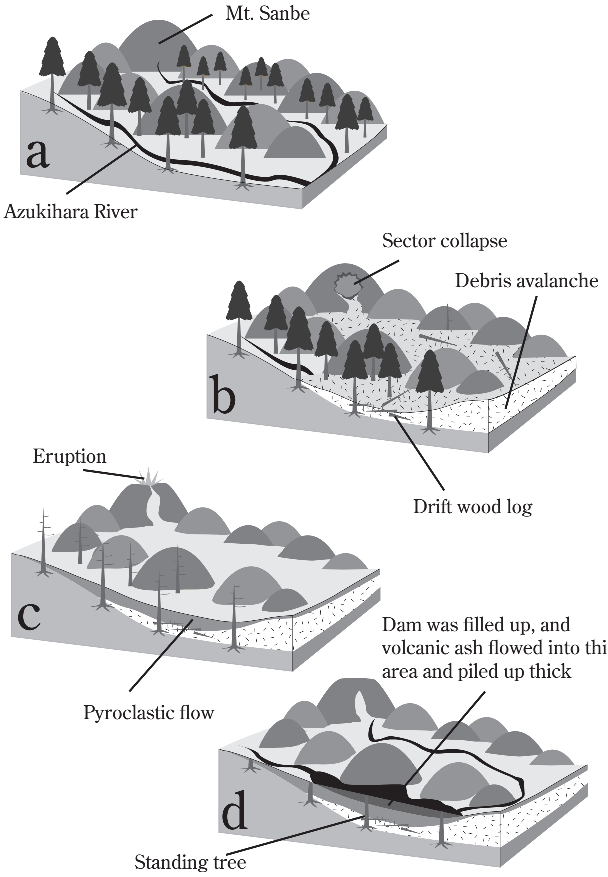

Fig. 2 Formation of the Sanbe-Azukihara buried forest (modified from Nakamura, 2003; Ohata et al., 2005). — a: Giant trees of *Cryptomeria japonica* grew at the northern foot of Mt. Sanbe at ca. 3500 yrs BP. b: Debris avalanche brought huge driftwood logs into the Azukihara area, damming up the Azukihara river to form a natural dam lake. c: Pyroclastic flows came down into the Azukihara area and covered the forest. d: The natural dam lake was filled up after the flow, and volcanic ash from the foot of Mt. Sanbe flowed into the Azukihara area, piled up thick, and buried the trees more deeply.

vegetation including a *Quercus serrata* community and *Castanopsis* sp. and *Quercus* subgen. *Cyclobalanopsis* sp. coppice forest, as well as plantations of *Pinus densiflora*, *Cryptomeria japonica*, and *Chamaecyparis obtusa*. In addition, the lowland is covered with paddy-field grass communities. The northern slope of Mt. Sanbe to the south of the study area is covered with the natural vegetation of the *Lindera umbellata–Fagus crenata*, and *Carpinus tschonoskii–Carpinus laxiflora* communities. Other slopes of Mt. Sanbe are occupied by *Sasa* grassland, an alliance of *Miscanthus sinensis*, an alliance of *Zoysia japonica*, and plantations of *Cryptomeria japonica*, *Chamaecyparis obtusa*, *C. pisifera*, and *Larix leptolepis*.

Sample collections

1. Species identification of buried trees

From 63 wood samples that Sato (2002, 2003a, b) recorded the position and diameter, we collected 56 wood samples for species identification. Seven remaining samples were identified by Mitsutani (2002, 2003) and Sato (2000, 2003b). Of these, 27 wood samples were from buried standing trees in the Sanbe-Azukihara Buried Forest Park, and 29 were from driftwood logs probably carried by a debris avalanche to the present site of the Large Exhibition Room of the Sanbe-Azukihara Buried Forest Park (Fig. 3).

2. Pollen analysis

Samples for pollen analysis were collected from Location 1 in the site of the Exhibition Room of the Sanbe-Azukihara Buried Forest Park and from Locations 2–4 in the site of the Large Exhibition Room (Fig. 3). At all the locations, the top horizons were the paleosoil (Second Black Soil) dated at ca. 3500 yrs BP buried by the debris avalanche (Figs. 5–6).

Methods

1. Species identification of buried trees

Thin wood sections were cut from buried trees for microscopic observation (Watanabe & Furuno, 2000). The sections were mounted with Canada balsam to make permanent preparations. All prepared wood samples are preserved at Archaeological Research Consultants, Inc., Matsue, Shimane, Japan. Permanent preparations of buried wood were identified under an optical microscope.

2. Pollen analysis

All samples were prepared by the procedures in Watanabe (1995). Fossil pollen grains were identified under an optical microscope. We counted more than 200 pollen grains of trees and shrubs for each sample, and all pollen grains of herbs and spores were counted for each sample. However, counting in some samples did not reach 200 pollen grains.

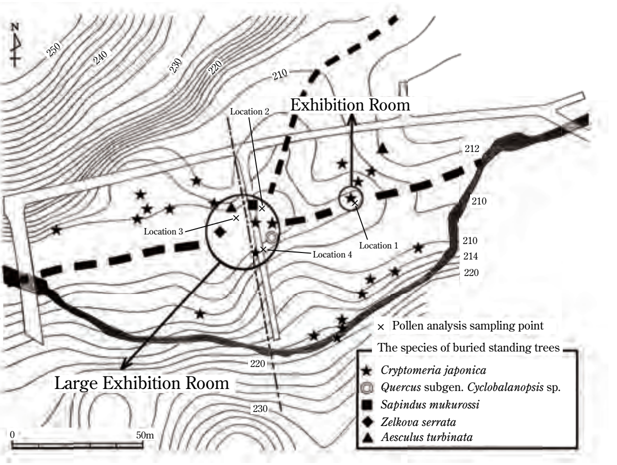

Fig. 3 Position of buried standing trees and sampling points for pollen analysis (Locations 1–4) in the Sanbe-Azukihara Buried Forest Park (modified from Sato, 2002).

Results

1. Species identification of buried trees

From 56 samples eight taxa were identified. Brief anatomical descriptions of eight taxa are given below with microscopic photographs of representative specimens (Fig. 4) to show the basis of identification.

Cephalotaxus harringtoniia K. Koch (Cephalotaxaceae) (Fig. 4: 1a–1c)

Coniferous wood made of tracheids, axial parenchyma cells (resin cells), and ray parenchyma cells. Resin canals absent. Growth ring boundaries moderately distinct. Transition from early- to latewood gradual. Helical thickenings present in tracheids. Rays consisting entirely of ray parenchyma cells. Cross-field pits are piceoid, generally 1–2 per cross-field.

Cryptomeria japonica D. Don (Taxodiaceae) (Fig. 4: 2a–2c)

Coniferous wood made of tracheids, axial parenchyma cells (resin cells), and ray parenchyma cells. Resin canals absent. Growth ring boundaries distinct. Transition from early- to latewood more or less abrupt. Axial parenchyma cells scattered in the transition zone from early- to latewood. Rays consisting entirely of ray parenchyma cells. Cross-field pits are taxodioid, 2–3 (generally 2) per cross-field.

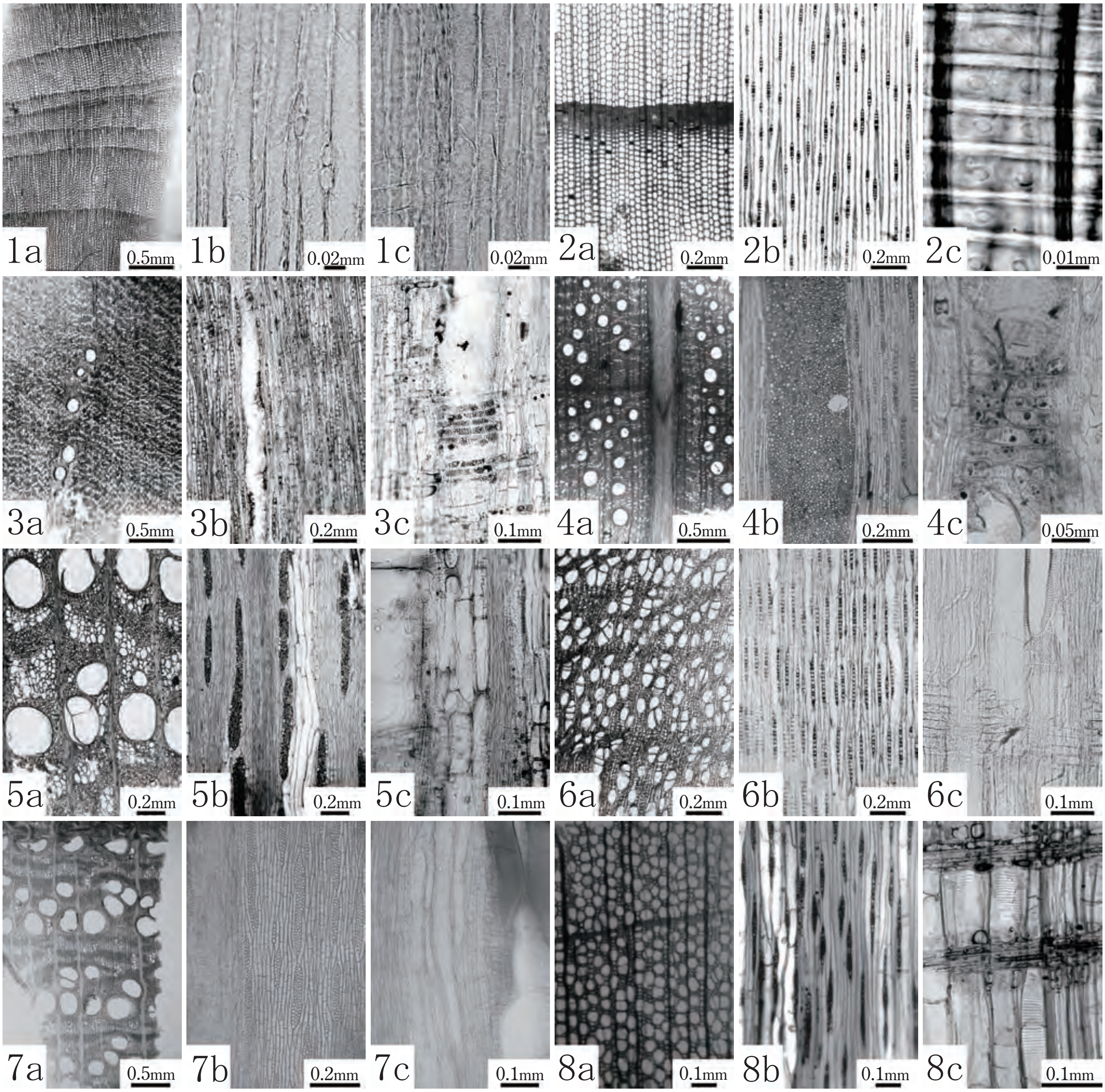

Fig. 4 Light micrographs of buried woods from the Sanbe-Azukihara buried forest. — 1a–1c: *Cephalotaxus harringtonia* (A-21). 2a–2c: *Cryptomeria japonica* (A-5). 3a–3c: *Castanopsis cuspidata or Quercus* subgen. *Cyclobalanopsis* sp. (A-22). 4a–4c: *Quercus* subgen. *Cyclobalanopsis* sp. (A-27). 5a–5c: *Zelkova serrata* (B-3). 6a–6c: *Aesculus turbinata* (A-8). 7a–7c: *Sapindus mukorossi* (A-28). 8a–8c: *Cercidiphyllum* sp. (A-29). a: cross section, b: tangential section, c: radial section.

Castanopsis cuspidata (Thunb.) Schottky or *Quercus* subgen. *Cyclobalanopsis* sp. (Fagaceae) (Fig. 4: 3a–3c)

Radial-porous wood. Vessels round or oval, exclusively solitary, 10–60 μm in diameter; perforation plates simple; vessel-ray pits vertical; commonly occluded with tyloses. Vasicentric tracheids present. Axial parenchyma abundant, apotracheal, diffuse-in-aggregates. Rays exclusively uniseriate and homogeneous, occasionally forming aggregate rays. From these characteristics, this specimen was identified as *Castanopsis cuspidata* or young *Quercus* subgen. *Cyclobalanopsis* before the formation of broad rays (Shimaji, 1962).

Quercus subgen *Cyclobalanopsis* sp. (Fagaceae) (Fig.

4: 4a–4c)

Radial-porous wood. Vessels round or oval, exclusively solitary, 20–70 µm in diameter; perforation plates simple; vessel-ray pits vertical; commonly occluded with tyloses. Vasicentric tracheids present. Axial parenchyma abundant, apotracheal, diffuse-in-aggregates and/or narrow bands up to two cells wide. Rays homogeneous, two distinct size present, consisting numerous uniseriate rays and extremely broad rays.

Zelkova serrata (Thunb.) Makino (Ulmaceae) (Fig. 4: 5a–5c)

Ring-porous wood. Earlywood vessel round or oval, 120–160 µm in diameter; lined solitarily in 1–2 rows along growth ring boundaries; latewood vessels very small and angular, numerous, in clusters; perforation plates simple; intervessel elements pits alternate; helical thickenings present in narrower vessel elements; tyloses present commonly in vessels. Axial parenchyma vasicentric. Rays heterogeneous, 1–9 (generally 6) cells wide, up to 400 µm in height; body ray cells procumbent with a single row of square marginal cells; prismatic crystals large and numerous in marginal cells.

Aesculus turbinata Blume (Hippocastanaceae) (Fig. 4: 6a–6c)

Diffuse-porous wood. Vessels, 30–50 µm in diameter, solitary or in radial multiples of 2–8; perforation plates simple; intervessel pits alternate; helical thickening present in vessel elements. Axial parenchyma in marginal bands of 1–2 cells wide consisting of parenchyma strands with 3–4 cells. Rays homogeneous, exclusively uniseriate and low; all rays storied.

Sapindus mukorossi Gaertn. (Sapindaceae) (Fig. 4: 7a–7c)

Ring-porous wood. Earlywood vessel round or oval, 200–350 µm in diameter; lined in 1–3 rows along growth ring boundaries; latewood vessels small, 30–50 µm in diameter, scattered in clusters; perforation plates simple; helical thickenings distinct in narrower vessel elements; colored deposits present in vessels. Axial parenchyma vasicentric to confluent and /or in bands in latewood. Rays homogeneous, 1–4 cells wide, up to 800 µm in height.

Cercidiphyllum sp. (Cercidiphyllaceae) (Fig. 4: 8a–8c)

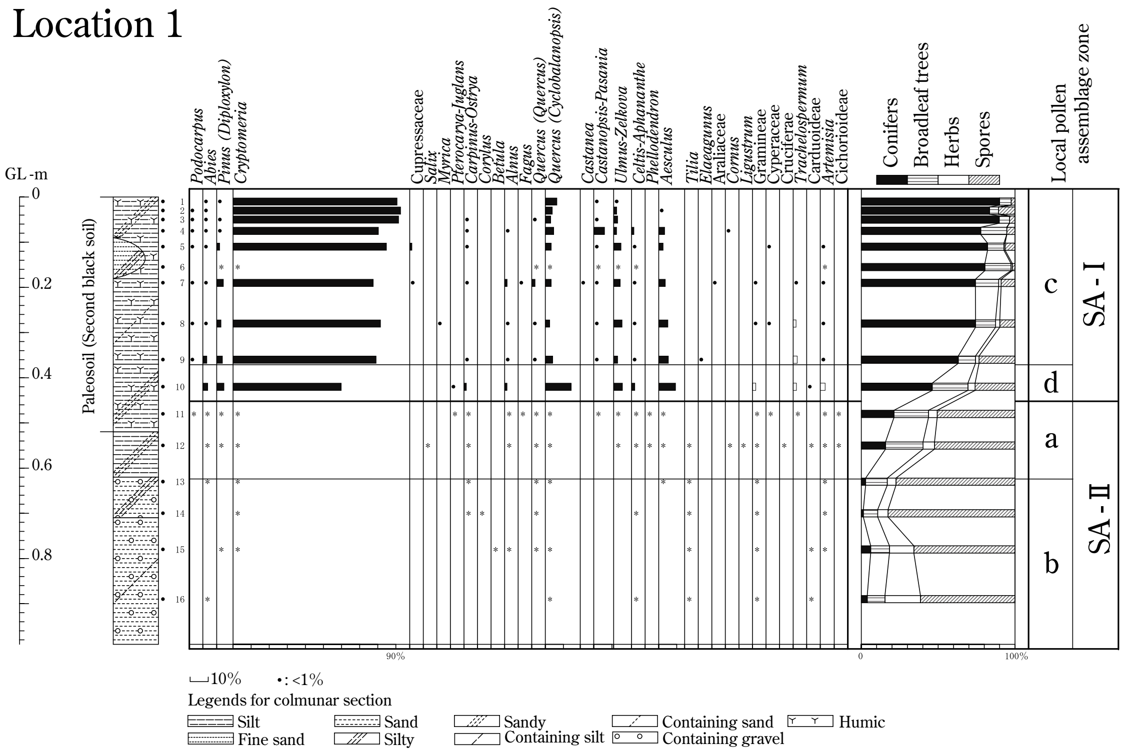

Fig. 5 Pollen diagram of Location 1 in the Sanbe-Azukihara Buried Forest Park. Percentages for each taxon are calculated based on the total arboreal pollen grain counts. Coniferous and broadleaved trees are shown by black spectra, and herbs are shown by white spectra. Only the presence of taxa is indicated by asterisks for samples with less than 200 pollen grain counts in total. Vertical changes in the ratio of conifers, broadleaf trees, herbs, and spores are shown on the right.

Diffuse-porous wood. Vessels angular, 40–70 μm in diameter, solitary or in radial or irregular multiples of 2–3; perforation plates scalariform, with many bars; tyloses present abundantly in vessels; vessel-ray pits opposite or scalariform. Fibers with bordered pits and thin-walled. Axial parenchyma in marginal and scanty.

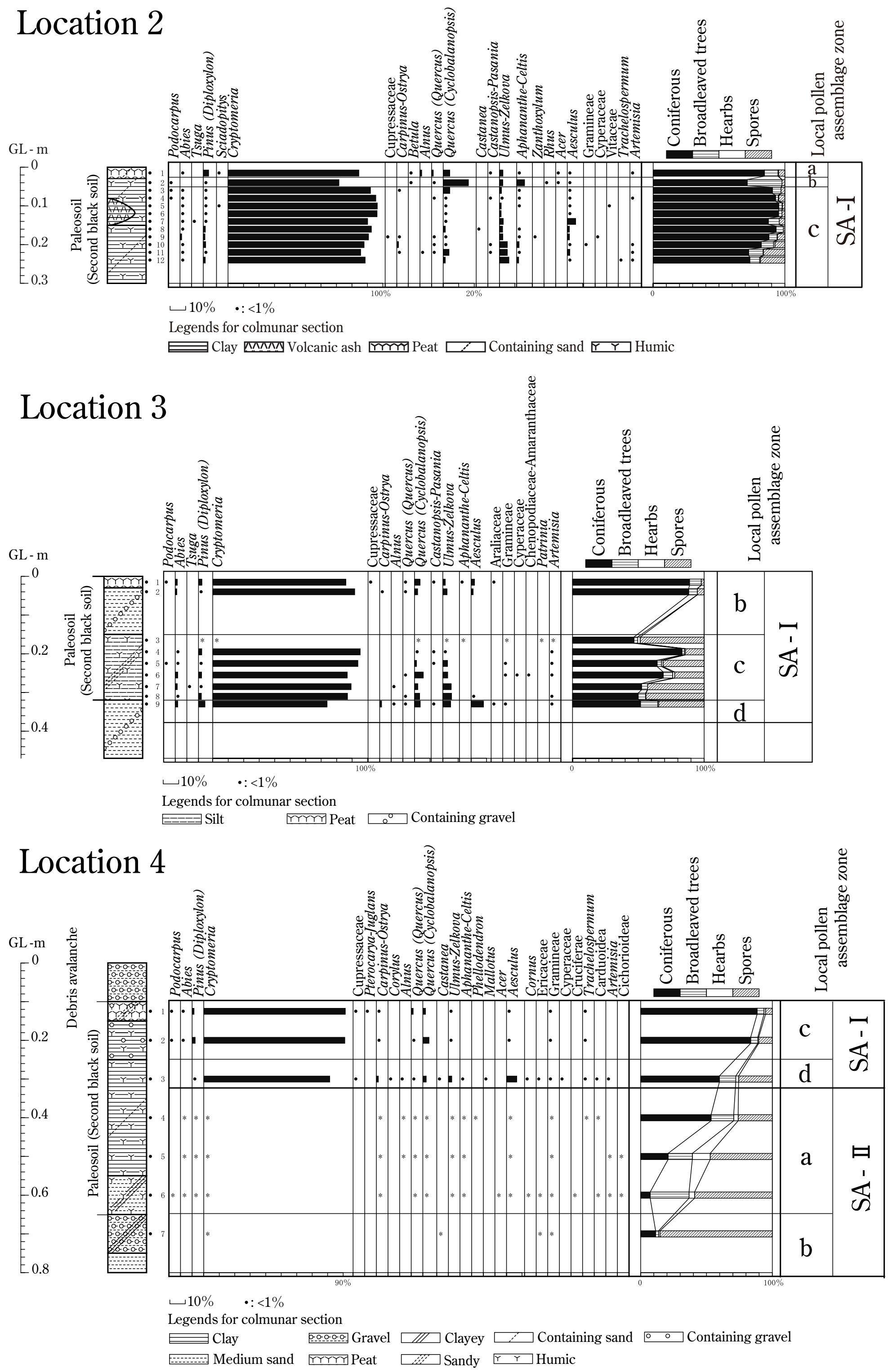

Fig. 6 Pollen diagrams of Locations 2, 3, and 4 in the Sanbe-Azukihara Buried Forest Park. See Fig. 5 for explanation.

Rays heterogeneous, 1–2 cells wide, up to 600 µm in height; body ray cells procumbent with a few rows of upright and/or square marginal cells.

2. Pollen analysis

From pollen diagrams of locations 1, 2, 3, and 4, two local pollen assemblage zones and six pollen subzones were recognized (Figs. 5–6).

SA-II: The counting of tree pollen grains is less than 200 grains. The ratio of herb pollen and spores was high in the lower part, and then suddenly decreased before the stage SA-I. These samples yielded little tree pollen and were difficult to do pollen zoning. However, the statistical validity of the change in the ratio of pollen from conifers, broadleaf trees and herbs, and spores is significantly high.

SA-IIb: Over 100 or 200 grains of pollen and spores were detected.

SA-IIa: Less than 100 grains of pollen and spores were detected.

SA-I: In this zone, the frequencies of *Cryptomeria* pollen are more than 60%, and broadleaf tree pollen such as *Quercus* subgen. *Cyclobalanopsis, Ulmus-Zelkova,* and *Aesculus* occurred continuously.

SA-Id: *Cryptomeria* pollen increased from 60% to 80%. *Quercus* subgen. *Cyclobalanopsis*, *Ulmus-Zelkova*, and *Aesculus* pollens occurred up to 14%.

SA-Ic: *Cryptomeria* pollen increased from 80% to 95%. *Quercus* subgen. *Cyclobalanopsis*, *Ulmus-Zelkova*, and *Aesculus* pollens decreased to 0-1 %.

SA-Ib: *Cryptomeria* pollen decreased to 72%. *Quercus* subgen. *Cyclobalanopsis* pollens increased up to 16%. *Ulmus-Zelkova* and *Aesculus* pollens increased to 1-2%.

SA-Ia: *Cryptomeria* pollen increased to 84%. *Pinus* subgen. *Diploxlon* pollen increased to 3%. *Quercus* subgen. *Cyclobalanopsis* and *Aesculus* pollens decreased to 2–4%.

3. Examination of paleovegetation

Species identification of the buried trees revealed the existence of a mixed forest of *Cryptomeria japonica* and broadleaf trees. *Cryptomeria japonica* was the dominant species, and broadleaf trees included *Castanopsis cuspidata*, *Quercus* subgen. *Cyclobalanopsis*, *Zelkova serrata*, *Aesculus turbinata*, and *Sapindus mukorossi* in the Azukihara area (Fig. 7). The composition of driftwoods transported by the debris avalanche was almost the same as that of standing trees. In addition to these tree species found in fossil woods, "pioneer plants"such as *Carpinus–Ostrya* and *Quercus* subgen. *Quercus* were detected by pollen analysis. Possibly pollen grains of these taxa came from secondary forests that covered the wasteland after the eruption of Mt. Sanbe at the Sanbe volcano stage VII (Fukuoka & Matsui, 2004). Or, it could be from canopy gaps near the Azukihara area.

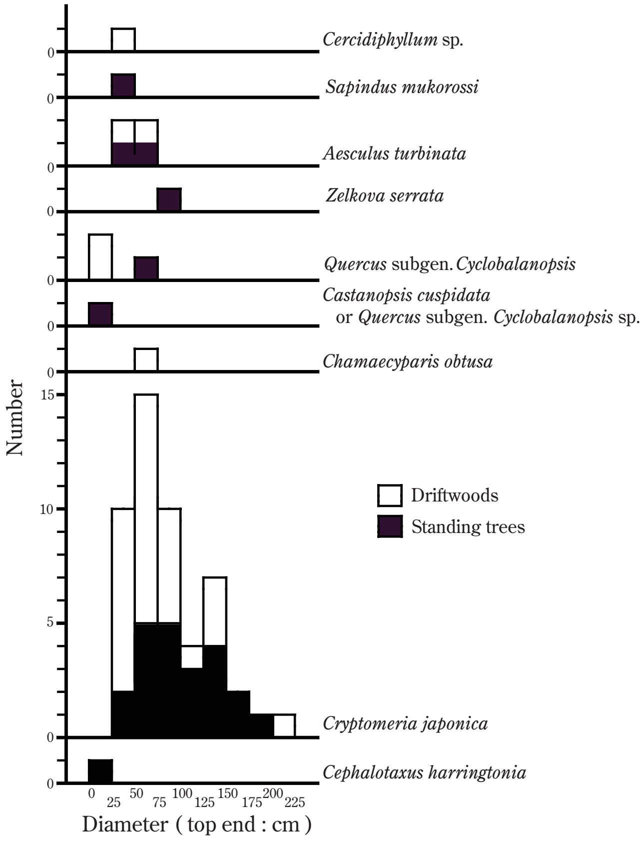

Fig. 7 The diameter distribution of standing trees and driftwoods in the Sanbe-Azukihara buried forest (including seven samples identified by Sato (2000, 2003b) and Mitsutani (2002, 2003)). Standing trees were bureid with ca. 13 m deep sediments. The diameter of standing trees and driftwoods were measured at the top end.

Discussion

1. Changes in paleovegetation

The upper part of the paleosoil of the buried forest included only volcanic ash layers of the Sanbe volcano stage VII, but not those of the Sanbe volcano stage VI (Matsui & Fukuoka, 2000). Thus, the forest was established on the paleosoil (Second Black Soil) formed during the Sanbe volcano stage VII.

As shown in the pollen assemblage zone SA-IIb, the Azukihara area was a wasteland consisting of herbs and ferns immediately after the Sanbe volcano stage VI. In SA-IIa zone, elements of a riparian forest such as

Aesculus, *Pterocarya-Juglans*, *Ulmus-Zelkova*, *Aphananthe-Celtis*, *Salix*, *Tilia*, and *Ligustrum* increased, and *Cryptomeria* pollen began to increase. In SA-I zone, *Cryptomeria* pollen is predominant in these riparian elements. Thus, in the Sanbe volcano stage VII, the Azukihara area changed from a wasteland to a riparian forest and then into a *C. japonica* forest with the paleosoil (Second Black Soil).

2. Condition for the expansion of *Cryptomeria japonica* forest

Tsukada (1980) thought that the refugia of *Cryptomeria japonica* were probably distributed over the Japan Sea coastal area of the central Chugoku region in the Last Glacial Maximum. The expansion of *C. japonica* was gradual during the late glacial and early postglacial stages, but it became faster when the climatic conditions such as precipitation and temperature became more suitable for the growth of this species. However, *C. japonica* did not predominate in the forest where soils were dry (Tsukada, 1982).

On the other hand, Takahara (1998) suggested that the refugia of *Cryptomeria japonica* did not exist in the central Chugoku region in the Last Glacial Maximum and indicated the following three possibilities that may have hindered the expansion of *C. japonica* in this region during the Holocene. The first one is the not enough precipitation for the development of *Cryptomeria japonica* forests. The second one is the prior expansion of *Quercus* subgen. *Cyclobalanopsis* forests to that of *C. japonica* forests. The third one is the prevention of the southward migration of *C. japonica* from a refugia in the Paleo-Oki peninsula by a rapid rise in the sea level in the late glacial stage (Takahara et al, 2001).

The views of these two researchers differ in considering the land conditions besides the precipitation, but agree in the prohibitive role played by the previously established vegetation. Contrary to these prevailing views, our study showed that, in some areas of the central Chugoku district during the Middle Holocene, *Cryptomeria japonica* forests existed and that the climatic conditions such as precipitation and temperature and the edaphic condition were appropriate for the growth of *C. japonica*

Acknowledgments

We express our gratitude to Shimane Prefecture for their support of this study. We also thank Dr. Shuichi Noshiro, the editor-in-chief, two anonymous referees, and Prof. Hiroaki Ishiga, Shimane University, for their helpful review of the manuscript. Further, we thank Mr. Tadashi Nakamura, Shimane Nature Museum of Mt. Sanbe (Sahimel), for offering the original figure.

References

Environment Agency, ed. 1982. *Actual vegetation map, Shimane 15, Sanbesan*. (in Japanese)
（環境庁編．1982．現存植生図島根県 15 三瓶山）

Environment Agency, ed. 1986. *Actual vegetation map, Shimane 14, Iwamioda*. (in Japanese)
（環境庁編．1986．現存植生図島根県 14 石見大田）

Fukuoka, T. & Matsui, S. 2004. Historical eruption style of Sanbe Volcano, Japan. *Bulletin of Sanbe Nature Museum* No. 2: 9–14. (in Japanese)
（福岡　孝・松井整司．2004．三瓶火山の噴火様式の変遷．島根県立三瓶自然館研究報告 No. 2: 9–14）

Matsui S. & Fukuoka T. 2000. A tentative name “Odori volcanic ashes” discovered from the humus soil of the neighborhood of A-9. *Sanbe-Azukihara Buried Forest research report (general reports, 1998–1999)*, 99–101. Division of Scene and Nature, Department of Environment and Life, Shimane Prefecture, Matsue. (in Japanese)
（松井整司・福岡　孝．2000．A-9 付近の腐植土壌中から発見された仮称「オドリ」火山灰について．三瓶埋没林調査報告書（平成 10 ～ 11 年度概報），99–101．島根県環境生活部景観自然課，松江）

Mitsutani, T. 2002. Examination by the dendrochronology of Sanbe-Azukihara Buried Forest (2). *Sanbe-Azukihara Buried Forest research report II (general reports, 2000–2001)*, 127–128. Division of Scene and Nature, Department of Environment and Life, Shimane Prefecture, Matsue. (in Japanese)
（光谷拓実．2002．三瓶小豆原埋没林の年輪年代法による検討(2)．三瓶埋没林調査報告書Ⅱ(平成 12 ～ 13 年度概報)，127–128．島根県環境生活部景観自然課，松江）

Mitsutani, T. 2003. Clarification from annual rings of Sanbe-Azukihara Buried Forest. *Sanbe-Azukihara Buried Forest research report III (investigation summaries, 1998–2002)*, 57–61. Division of Scene and Nature, Department of Environment and Life, Shimane Prefecture, Matsue. (in Japanese)
（光谷拓実．2003．「三瓶小豆原埋没林」の年輪からわかったこと．三瓶埋没林調査報告書Ⅲ（平成 10 ～ 14 年度調査まとめ），57–61．島根県環境生活部景観自然課，松江）

Nakamura, T. 2003. The sediments filling Sanbe-Azukihara Buried Forest. Based on the excavation investigation of the buried standing tree A-5 and A-9. *Sanbe-Azukihara Buried Forest research report III (investigation summaries, 1998–2002)*, 10–14. Division of Scene and Nature, Department of Environment and Life, Shimane Prefecture, Matsue. (in Japanese)
（中村唯史．2003．埋没林を埋積する地層について（埋没立木 A-5，A-9 発掘調査をもとに）．三瓶埋没林調査報告書Ⅲ（平成 10 ～ 14 年度調査まとめ），53–56．島根県環境生活部景観自然課，松江）

Ohata, J., Nakamura, T., Fukuoka, T. & Yoshiya, T. 2005. Sanbe Azukihara Buried Forest—Time capsule of reviving the Jomon Period. The Shimane Nature Museum of Mt. Sanbe, Shimane Prefecture, Ooda. (in Japanese)

（大畑純二・中村唯史・福岡　孝・葭矢崇司．2005．三瓶小豆原埋没林　よみがえる縄文時代のタイムカプセル．島根県立三瓶自然館，大田）

Sato, H. 2000. Survey of excavation. *Sanbe-Azukihara Buried Forest research report (general reports, 1998–1999)*, 22–30. Division of Scene and Nature, Department of Environment and Life, Shimane Prefecture, Matsue. (in Japanese)

（佐藤仁志．2000．掘り出し調査．三瓶埋没林調査報告書(平成10～11年度概報)，22–30．島根県環境生活部景観自然課，松江）

Sato, H. 2002. Survey of excavation. *Sanbe-Azukihara Buried Forest research report II (general reports, 2000–2001)*, 11–25. Division of Scene and Nature, Department of Environment and Life, Shimane Prefecture, Matsue. (in Japanese)

（佐藤仁志．2002．掘り出し調査．三瓶埋没林調査報告書II（平成12～13年度概報)，11–25．島根県環境生活部景観自然課，松江）

Sato, H. 2003a. The distribution of drift trees in Large Exhibition Room (investigation summaries). *Sanbe-Azukihara Buried Forest research report III (investigation summaries, 1998–2002)*, 35–37. Division of Scene and Nature, Department of Environment and Life, Shimane Prefecture, Matsue. (in Japanese)

（佐藤仁志．2003a．縄文の森発掘展示棟内の流木の分布．三瓶埋没林調査報告書III(平成10～14年度調査まとめ)，35–37．島根県環境生活部景観自然課，松江）

Sato, H. 2003b. The results of measuring the tree trunks. (including the results in the past years). *Sanbe-Azukihara Buried Forest research report III (investigation summaries, 1998–2002)*, 45–48. Division of Scene and Nature, Department of Environment and Life, Shimane Prefecture, Matsue. (in Japanese)

（佐藤仁志．2003b．樹幹測定結果（過年度分を含む)．三瓶埋没林調査報告書III（平成10～14年度調査まとめ)，45–48．島根県環境生活部景観自然課，松江）

Shimaji, K. 1962. Anatomical studies on the phylogenetic interrelationship of the genera in the Fagaceae. *Bulletin of the Tokyo University Forests* No. 57: 1–64, pl. 1–26.

Takahara, H. 1998. The change of *Cryptomeria japonica* forest. *Illustrated Review: Vegetation history in Japan Islands* (Y. Yasuda & N. Miyoshi, eds.), 207–223. Asakura Publishing Co., Tokyo. (in Japanese)

（高原　光．1998．スギ林の変遷．図説 日本列島植生史（安田喜憲・三好教夫編)，207–223．朝倉書店，東京）

Takahara, H., Fujiki T., Miyoshi N. & Nishida S. 1997. Vegetation history since the middle Holocene around Orogatawa Moor, Okayama Prefecture. *Japanese Journal of Palynology* **43**: 97–106. (in Japanese)

Takahara H. Tanida K. & Miyoshi N. 2001. The full-glacial refugium of *Cryptomeria japonica* in the Oki Islands, western Japan. *Japanese Journal of Palynology* **47**: 21–33.

Tsukada M. 1980. The history of Japanese cedar: the last 15,000 years. *Kagaku (Science)* **50**: 538–546. (in Japanese)

（塚田松雄．1980．杉の歴史：過去一万五千年間．科学**50**: 538–546）

Tsukada M. 1982. *Cryptomeria japonica*: glacical refugia and late-glacial and postglatial migration. *Ecology* **63**: 1091–1105.

Watanabe, M. 1995. Pollen analysis. *Method of Archaeology Material Analysis* (I. Taguchi & T. Saito, eds.), 84–85. New Science Co., Tokyo. (in Japanese)

（渡辺正巳．1995．花粉分析．考古資料分析法（田口　勇・齋藤　努編)，84–85．ニューサイエンス社，東京）

Watanabe, M. & Furuno, T. 2000. The result of species identification of buried trees. *Sanbe-Azukihara Buried Forest research report I (general reports, 1998–1999)*, 48–63. Division of Scene and Natural, Department of Environment and Life, Shimane Prefecture, Matsue. (in Japanese)

（渡辺正巳・古野　毅．2000．樹種分析結果．三瓶埋没林調査報告書III（平成10～11年度概報)，48–63．島根県環境生活部景観自然課，松江）

(2009年5月18日受理)