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Short communication

Naoko Sasaki[1], Tatsuichiro Kawano[2], Hikaru Takahara[2] and Shinya Sugita[3]: Phytolith evidence for the 700-year history of a dwarf-bamboo community in the sub-alpine zone of Mt. Kamegamori, Shikoku Island, Japan

佐々木尚子[1]・河野樹一郎[2]・高原　光[2]・杉田真哉[3]：植物珪酸体から明らかになった石鎚山系瓶ヶ森における過去 700 年間のササ草原の歴史

Introduction

The sub-alpine zone of the Ishizuchi mountain range is characterized by the parkland landscape dominated by the dwarf-bamboo thicket. Two major hypotheses have been proposed to explain the origin and cause of the landscape. Wada et al. (1939) and Nakamura (1969) suggested that the dominance of dwarf bamboos in this area reflects past fire disturbances. On the other hand, Matsui (1995) hypothesized that the strong wind prevented the forest development in the sub-alpine zone over the region, resulting in the persistence of dwarf bamboos in the unforested areas. Sasaki (2003) tried to test those hypotheses using fossil pollen and charcoal from small hollows on Mt. Kamegamori in the mountain range. Because of the difficulties in distinguishing dwarf-bamboo pollen from other Gramineae pollen types, it was inconclusive whether dwarf-bamboos expanded into the area after fire events or were persistent for a long time. This short note summarizes a new data set of phytoliths preserved in the same sediment cores that Sasaki (2003) used for pollen analysis, and elucidated that dwarf-bamboos have indeed been dominant over the last 700 years.

Morphology of Gramineae phytoliths varies among subfamilies, tribes, or genera (Twiss et al., 1969; Kondo & Sase, 1986). Although exceptions exist (Brown, 1984; Mulholland, 1989), modern and fossil phytolith assemblages have been used for reconstructing the grassland history (Fredlund & Tieszen, 1994; 1997; Alexandre et al., 1997; Fearn, 1998). In Japan, for example, archeologists and paleoecologists have used phytolith records to investigate the origin of the rice agriculture (Fujiwara, 1982; Fujiwara & Sugiyama, 1984) or to reconstruct past vegetation (Sase et al., 1990; Sugiyama, 1999). Advances in the classification of phytolith morphology (Sugiyama & Fujiwara, 1986; Kondo & Ootaki, 1992) now allow us to distinguish phytoliths of bamboos and dwarf-bamboos from others in Gramineae and make possible the study of the history and impact of the spread of bamboos into forests, one of the major problems foresters and ecologists have faced over the last few decades.

Our finding of the dwarf bamboo phytoliths in the sediments provides a new insight into the dynamics of the dwarf bamboo–*Abies homolepis* Sieb. et Zucc. parkland community on Mt. Kamegamori and its vicinity. We briefly describe the regional setting of the study area, then explain the classification scheme of the phytolith morphotypes of bamboos and dwarf bamboos, and reconstruct the vegetation history using the phytolith record and the pollen and charcoal profiles from Sasaki (2003).

Study area and method

Mt. Kamegamori (1896 m a.s.l.) is located 10 km east of Mt. Ishizuchi, the highest peak of the Ishizuchi mountain range, central Shikoku Island (Fig. 1). Annual precipitation is ca. 2600 mm at Jyojyusha (1280 m a.s.l.), and mean annual temperature at 1800 m elevation is estimated to be 4°C (Kuma meteorologi-

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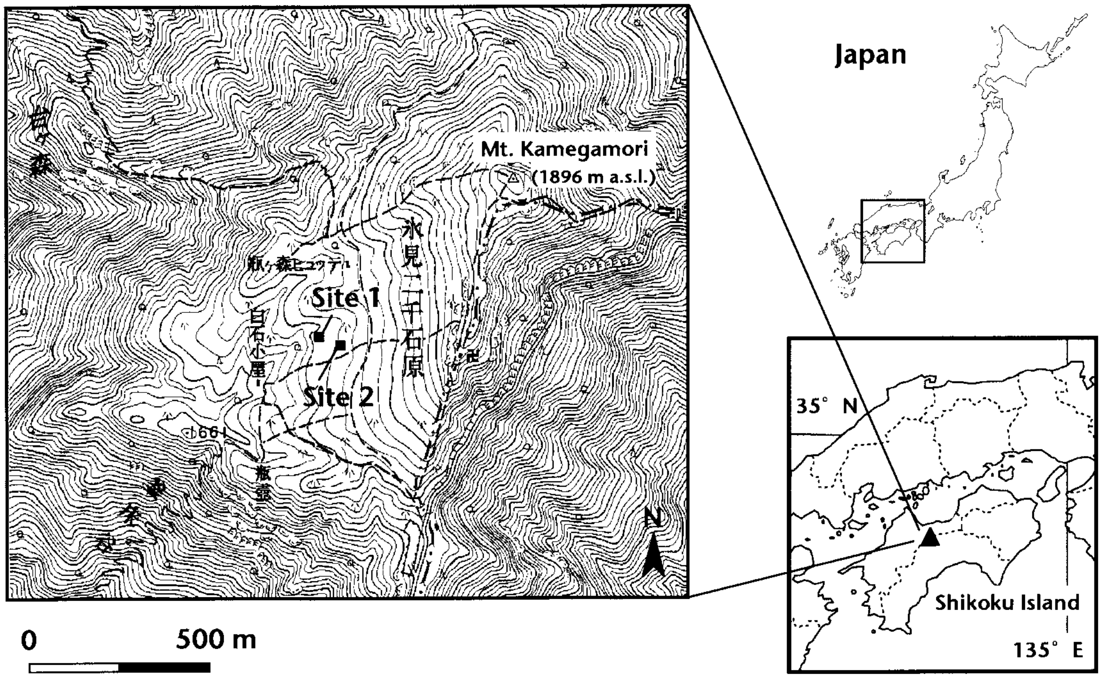

Fig. 1 Locations of coring sites (solid squares). The map is part of the 1 : 25,000 topographical map "Kamegamori" issued by the Geographical Survey Institute of Japan.

cal station, Japan Meteorological Agency, 2001). The 40 ha parkland covers the southeastern slope of the mountain above 1600 m and is dominated by two species of dwarf bamboo, *Sasa tsuboiana* Makino and *Sasa palmata* (Marliac) Nakai. In the parkland, patches of *Abies homolepis* stands occur, often including *Acer sieboldianum* Miq., *Acer shirasawanum* Koidz., and *Cornus brachypoda* C. A. Mey., and individual trees of *Abies homolepis*, *Rhododendron tschonoskii* Maxim., and *Pinus parviflora* Sieb. et Zucc. (subgen. Haploxylon) are scattered. *Betula ermanii* Cham. and *Salix* spp. trees grow along streams.

Four sediment cores (54–72 cm long) containing well-decomposed organic matter were collected in 1999 from four small hollows in the parkland, using a Thinwall Sampler (Sasaki, 2003). For phytolith analysis, we used a 72 cm core from Site 1 and 54 cm one from Site 2, and sub-sampled 1 cm^3 sediments at 5 to 10 cm intervals. Assuming constant sedimentation rates in these hollows, the temporal interval of sub-samples were estimated to be ca. 50 years for Site 1 and ca. 100 years for Site 2.

Sub-samples were processed by the wet ashing extraction method (Pearsall, 1989). Organic matter was removed with a hydrogen peroxide treatment (30% H_2O_2 at simmering temperature on hotplate for one hour or until reaction finished). Large particles and debris such as gravels and rootlets were removed with sieving through 250-μm mesh. We removed iron and aluminum oxides with HCl (3N HCl at 90°C in hot water bath for 20–60 minutes). Small particles were removed by sedimentation based on Stoke's law. Prior to extraction, a known amount of glass beads, 45 μm in diameter, were added to each sub-sample for estimating the concentration of phytoliths. After drying in an oven (70°C over night), samples were mounted on to glass slides in Eukitt mounting medium. For each sample, at least 200 grass short cell phytoliths were counted at × 400 magnification.

Phytolith classification

The phytolith classification follows Kondo & Sase (1986), Mulholland & Rapp (1992), and Sugiyama & Fujiwara (1986). We also referred to the modern reference samples prepared and archived at the Forest Dynamics Laboratory, Kyoto Prefectural University.

In Japan, subfamily Bambusoideae includes 12 genera and is divided into two groups, the bamboo group and the dwarf bamboo group, based on the deciduousness of their culm-sheaths (Ohwi & Kitagawa, 1983). The genus *Sasa* belongs to the dwarf bamboo group. Sase & Kondo (1974) recognized a characteristic short cell phytolith type in two species of *Sasa*. This phytolith is saddle-shaped with wrinkles, and was called

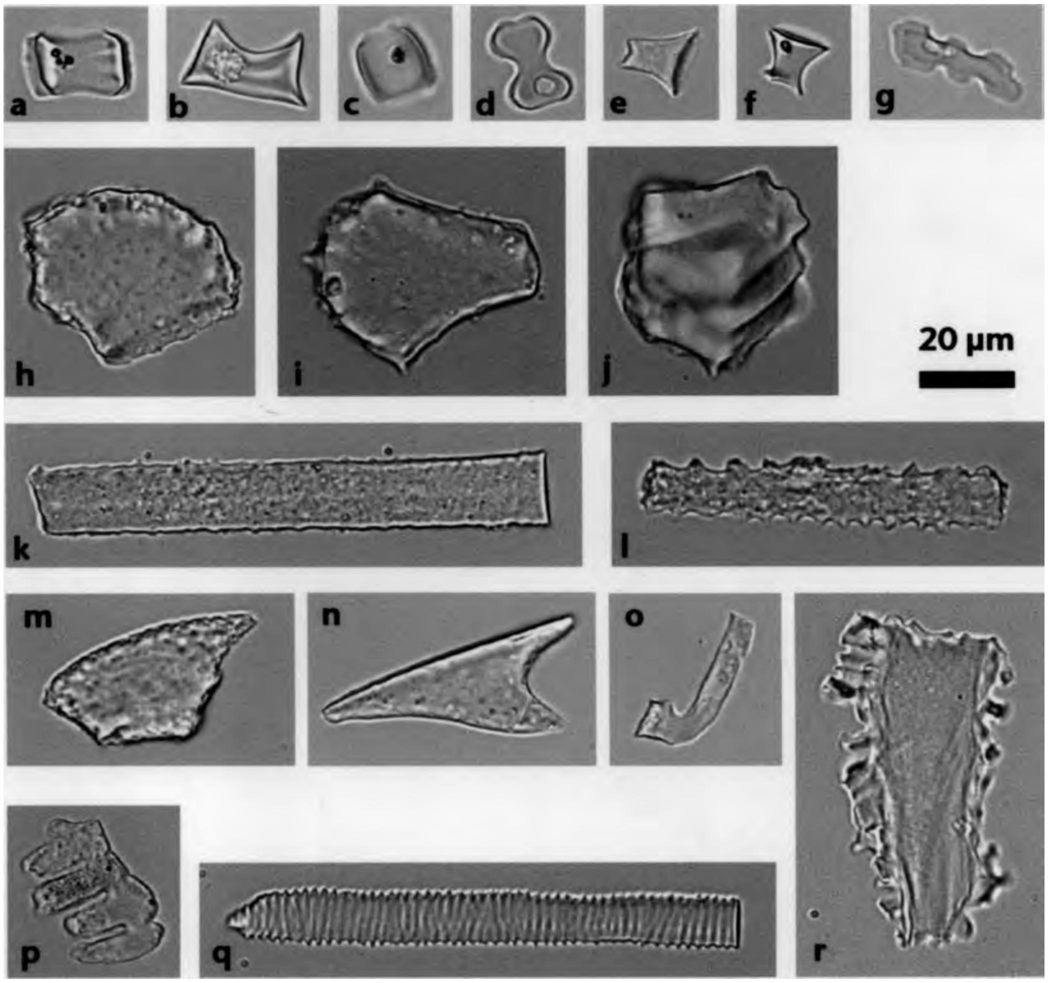

Fig. 2 Phytolith morphotypes extracted from sediment cores collected on Mt. Kamegamori. — a, b: bambusoid (saddle-shaped with wrinkles). — c: saddle. — d: dumbbell. — e, f: rondel. — g: crenate. — h, i: dwarf bamboo type bulliform. — j: bamboo type bulliform. — k, l: elongate. — m, n: point-shaped. — o: pipe-shaped. — p: spine-shaped. — q: vascular cell. — r: tongue sole type.

"Bambusoid class" by Kondo & Sase (1986). Kondo & Ootaki (1992) examined 62 species in 11 genera of Bambusoideae and observed the "Bambusoid class" phytolith not only in *Sasa*, but also in all the other genera examined. "Bambusoid" (Fig. 2a, b) in this paper corresponds to their "Bambusoid class". Sugiyama & Fujiwara (1986) examined bulliform cell phytoliths from 46 species in 13 genera of Bambusoideae, including some exotic species, and reported two morphotypes in bulliform cell phytoliths. "Type A" is relatively small and three-dimensional and belongs mainly to the bamboo group plants; "Type B" is relatively large and flat and belongs to the dwarf bamboo group including *Sasa* (Sugiyama & Fujiwara, 1986). "Bamboo type bulliform" (Fig. 2j) and "dwarf bamboo type bulliform" in this paper (Fig. 2h, i) correspond to "Type A" and "Type B", respectively. In this study, we used the combination of bambusoid and dwarf bamboo type bulliform morphotypes to infer phytoliths from the dwarf bamboo group.

Results

We classified phytoliths into 14 morphotypes: bambusoid (Fig. 2a, b), saddle (Fig. 2c), dumbbell (Fig. 2d), rondel (Fig. 2e, f), crenate (Fig. 2g), dwarf bamboo type bulliform (Fig. 2h, i), bamboo type bulliform (Fig. 2j), other type bulliform, elongate (Fig. 2k, l), point-shaped (Fig. 2m, n), pipe-shaped (Fig. 2o), spine-shaped (Fig. 2p), vascular cell (Fig. 2q), tongue sole type (Fig. 2r), and unclassified. "Tongue sole type" in Fig. 2r is the one described by Kondo & Sase (1986) from *Sasa* spp. without any morphotype name.

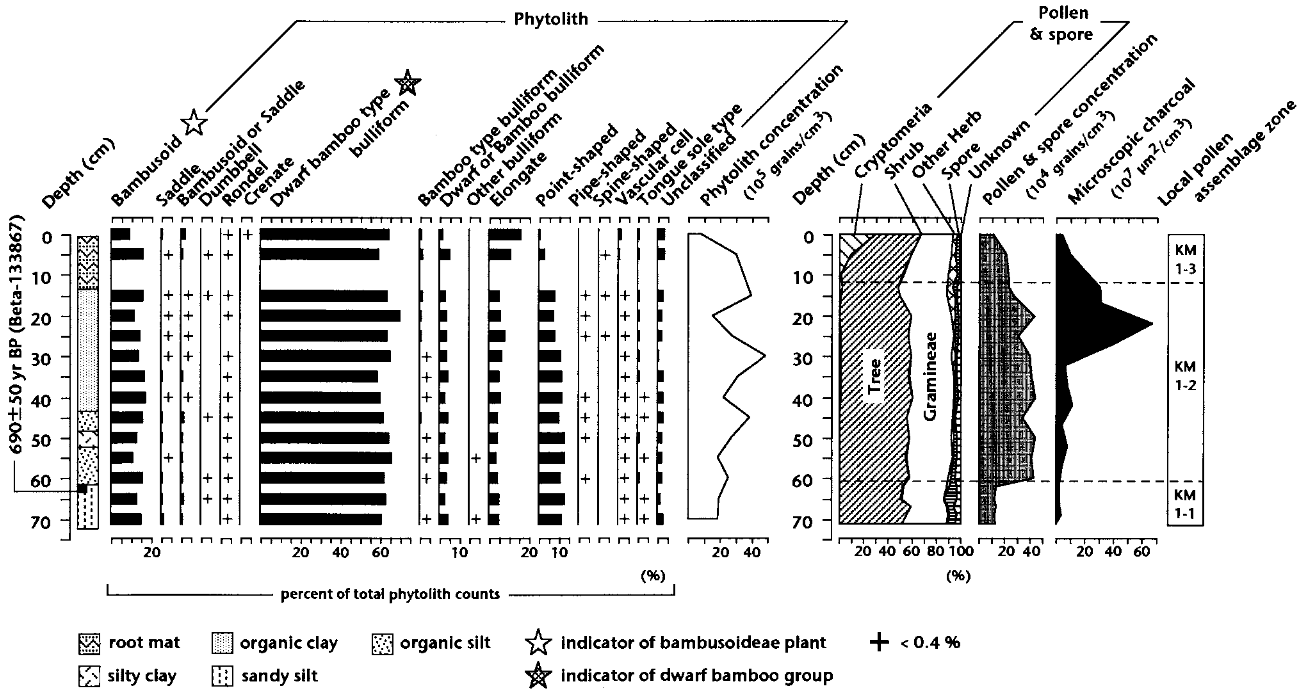

Fig. 3 Phytolith, pollen, and charcoal analyses at Site 1 on Mt. Kamegamori. Pollen and charcoal diagrams are based on Sasaki (2003). Three local pollen assemblage zones were established based on pollen percentages of the major tree taxa. KM1-1 is characterized by relatively high percentages of *Ulmus/Zelkova* pollen. In KM1-2, charcoal concentration peaks along with *Fagopyrum* pollen. In KM1-3, *Cryptomeria japonica* pollen dramatically increased, reflecting the widespread planting of this species started ca. 100 years ago in the region. Concentration of microscopic charcoal is expressed as the projection area of charcoal particles per unit volume (µm^2/cm^3) measured on the pollen slides with an image analysis system.

Throughout the cores at Site 1 (Fig. 3) and Site 2 (Fig. 4), dwarf bamboo type bulliform (50–69%) and bambusoid (11–17%) were the most common in the phytolith assemblages. Percentages of saddle, dumbbell, rondel, and crenate morphotypes, which indicate other subfamilies in Gramineae, were very low (<1%). Phytolith assemblages from Sites 1 and 2 completely lacked tree phytoliths (Figs. 3 & 4). Phytolith concentrations varied between 8 and 48 x 10^5 grains/cm^3 at Site 1 (Fig. 3) and between 6 and 64 x 10^5 grains/cm^3 at Site 2 (Fig. 4). The phytolith concentration was lowest in the surface sediments at both sites.

Discussion

The dominance of two morphotypes, bambusoid and dwarf bamboo type bulliform, throughout the cores indicates dominance of the dwarf bamboo group in the study area. In the area dominated by dwarf-bamboos in the pseudo-alpine zone of Mt. Tairappyo (1984 m a.s.l.) in central Japan, Kariya et al. (2004) showed that, at the top of the sediment core, "Bambusoideae" phytoliths including "dwarf bamboo type bulliform" and "bamboo type bulliform" in our classification were the most dominant among bulliform phytolith morphotypes. Their study indicated that the areas dominated by bamboos or dwarf bamboos could potentially be identified using phytolith assemblages in sediments. The absence of tree phytoliths in our phytolith data suggests that trees have been rare in the area surrounding our study sites. Even without the closed canopy, modern phytolith assemblages from riparian forest, oak grove, and "pine wood" in the northern Mediterranean show high proportions of tree phytoliths (13.8–21.0% of total phytoliths identified) (Delhon et al., 2003).

The dominance of dwarf bamboos in our study area was not, however, sustained by fire events. The changes in charcoal occurrence in the sediments did not correspond to the changes in the phytolith or pollen assemblages over the last 700 years (Figs. 3 & 4; Sasaki, 2003). At Site 1, after a major peak of charcoal con-

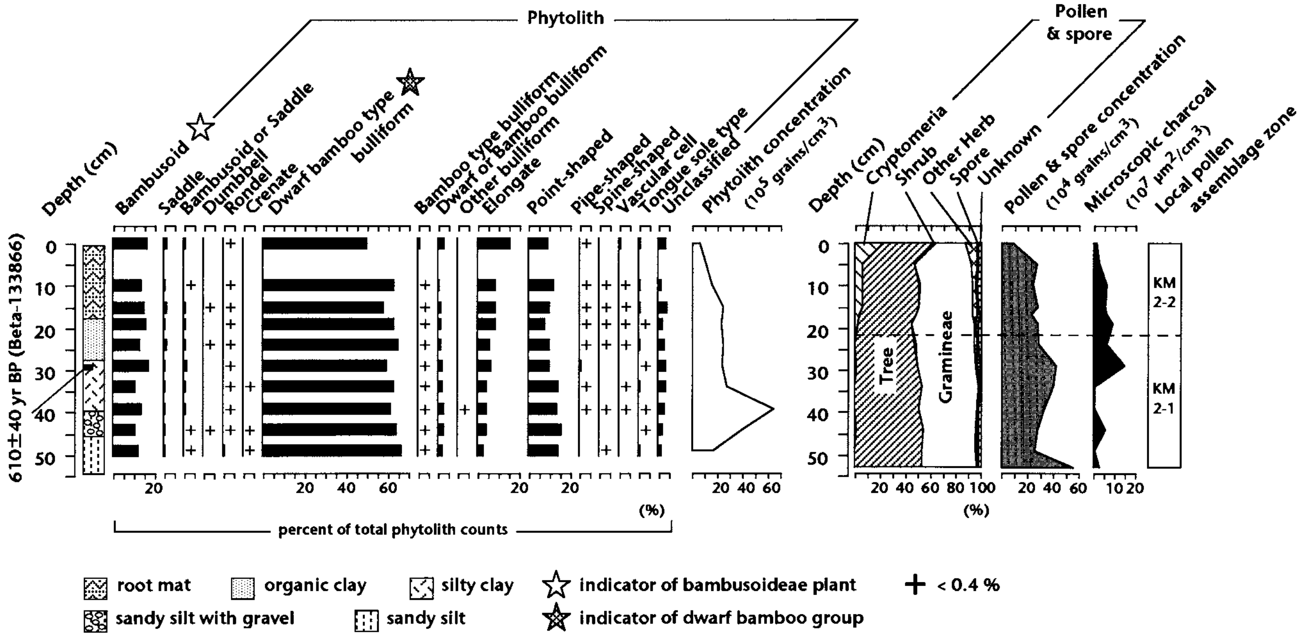

Fig. 4 Phytolith, pollen and charcoal analyses at Site 2 on Mt. Kamegamori. Pollen and charcoal diagrams are based on Sasaki (2003). Two local pollen assemblage zones were established based on pollen percentages of the major tree taxa. In KM2-1, deciduous tree pollen is dominant. In KM2-2, *Cryptomeria japonica* pollen increased, reflecting the widespread planting of this species started ca. 100 years ago in the region. See Fig. 3 for the measurment of concentration of microscopic charcoal.

centration at 22 cm (ca. 200 years ago), pollen percentage of Gramineae slightly increased, and the relative abundance of tree pollen declined (Fig. 3). The phytolith assemblages before and after the charcoal peak did not show a major change. Although phytolith concentration declined after the charcoal peak, phytolith and charcoal concentrations did not show clear correlations in the older parts of the sediment at Site 1 (Fig. 3). At Site 2, phytolith assemblages and concentration, and pollen percentage of Gramineae did not change significantly at 30–10 cm, where charcoal concentration was relatively high (Fig. 4). Thus, the hypothesis that fire disturbances have sustained the dominance of dwarf bamboos is not supported by the phytolith and charcoal records.

For accurate interpretation of the phytolith assemblages, the following basic factors should be studied. The amount of phytoliths produced by different species of trees and Gramineae plants (grasses and bamboos) varies substantially (Takachi et al., 2001). The abundance and composition of the phytolith morphotypes vary among taxa in Gramineae, as well as among the different parts of individual plants (Brown, 1984; Mulholland, 1989). Further compilation of modern phytolith assemblages and influx in grasslands, bamboo stands, and dwarf bamboo parkland in Japan is necessary for the objective reconstruction and interpretation of fossil records.

The phytolith records in our study show that the species composition and spatial structure of the parkland on Mt. Kamegamori have not changed over the last 700 years. This conclusion is consistent with those obtained from the pollen records and the written documents on the landscape of the Edo Period (Sasaki, 2003). At least over the last 700 years, fires did not cause the spread and dominance of dwarf bamboos in this area. The wind-disturbance hypothesis is still a viable alternative, but difficult to prove by the fossil records alone. A longer record of the vegetation history is necessary to elucidate the origin and maintenance of the dwarf-bamboo dominated parkland in this area.

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