A 7500-year history of intentional fires and changing vegetation on the Soni Plateau, Central Japan, reconstructed from macroscopic charcoal and pollen records within mire sediment

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Abstract

Macroscopic charcoal and pollen in mire sediments from the Soni Plateau, Central Japan, were evaluated to clarify intentional fire history and relationship between vegetation transition and anthropogenic fire or climate change. The sediments deposited in recent centuries, when fire probably occurred every year, include a number density of macroscopic charcoal fragments exceeding 100 fragments/cm^3. High charcoal abundances (> 100 fragments/cm^3) were also recognized in sediments deposited at ~7000 cal BP and from 1500 cal BP to the present. Sediments deposited between 7000 and 1500 cal BP have a low abundance of charcoal fragments (< 100 fragments/cm^3, but mainly < 20 fragments/cm^3). These results, combined with the pollen record, indicate that during the period until 1,500 cal BP (except for ~7000 cal BP), forests of *Abies*, *Quercus*, and *Fagus* developed in a largely fire-free environment in and around the plateau. In this period vegetation transition was mainly influenced by climate change as follows; between 7500 and 6500 cal BP deciduous broadleaf forest grew under cool-temperate conditions; between 6500 and 5500 cal BP evergreen broadleaf forest were expanded under warming; between 5500 and 1500 cal BP evergreen broadleaf forest were developed probably under warm conditions with much precipitation. Frequent fires during a short period at ~7000 cal BP, probably due to human activities, possibly resulted in disturbance of forest, although *Castanea* forest subsequently developed across the plateau following this fire-prone period. After ~1500 cal BP (dated at least 1000 cal BP), periodic intentional fires resulted in the development and persistence of grassland dominated by Gramineae.

Keywords Intentional fire · Charcoal fragment · Vegetation transition · Climate transition · Pollen record · Grassland · Holocene

1. Introduction

Under conditions of high precipitation and a temperate climate, forest has come to cover most of the Japanese Islands. However, small areas within Japan contain grassland that is intentionally burnt each year to enhance its survival. The grassland areas are considered to have expanded over time in response to frequent intentional fires (called "Yama-yaki" in Japanese) in Japan until at least 100 years ago (e.g., Mizumoto, 2003; Ogura, 2009). However, the history of fires and the expansion of grassland in Japan in response to fires remain poorly understood.

The record of macroscopic charcoal in lake and mire sediments is commonly examined to reconstruct the local history of fires (e.g., Long et al., 1998; Millspaugh et al., 2000; Brunelle and Anderson, 2003), as macroscopic charcoal fragments are not transported far from their source before settling (e.g., Whitlock and Larsen, 2001). Long et al. (1998) and other studies calculated the accumulation rates of charcoal particle number (CHAR) by analyzing contiguous sediment samples and estimated the fire frequency in the local area. The authors examined charcoal records in sediments deposited in areas where the fire frequency is at most one fire every several decades. Few studies have performed such an analysis in areas where fires occurred frequently (approximately every year) and for which the recent fire history is known.

The aims of the present study are to clarify intentional fire history and the relationship between vegetation transition and climate change or anthropogenic fire. The focus is on (1) clarifying how frequent fires in grassland areas are preserved as a charcoal record in sediment, (2) reconstructing the fire history in recent millennia in a local area in Japan where grassland is burnt annually, and (3) investigating changing vegetation patterns related to fire in the study area. To this end, the records of macroscopic charcoal and pollen within mire sediments on the Soni Plateau, Central Japan, which is a grassland area that has been burnt intentionally every year and for which the fire history is known for the past 100 years, were evaluated. This approach is adopted because the recent fire history would provide the information required to reconstruct the fire history over thousands of years by comparing the known fire history with the charcoal record preserved in sediments.

2. Study Site

The Soni Plateau, located in Central Japan, is a small bowl-shaped depression of 600–700 m in diameter at an altitude of 700–850 m (Fig. 1). Okame-ike mire (2.4 ha) is located in the bottom of the depression. Consequently, the catchment of the mire largely coincides with the extent of the depression. According to meteorological data recorded at Oouda Climatological Station (34°29′01″N, 135°56′01″E; elevation, 349 m; Japan Meteorological Agency, 2001), located ~12 km from Soni Plateau, the annual mean temperature (1979–2000) is 12.7°C. The annual precipitation (1979–2000) is about 1728 mm at Soni Climatological Station (34°31′01″N, 136°09′07″E; elevation, 610 m; Japan Meteorological Agency, 2001), located in the plateau.

The Soni Plateau is situated in the cool temperate zone. The climax vegetation in this area is cool-temperate deciduous broad-leaved forest, but most of the present vegetation consists of plantations of

Japanese cedar (*Cryptomeria japonica*) and Japanese cypress (*Chamaecyparis obtusa*) or secondary forest of Japanese red pine (*Pinus densiflora*) and deciduous oak (*Quercus serrata*), except for the area of the depression. Almost the entire bowl-shaped depression (ca. 38 ha) on the plateau is covered with grassland, dominated by Japanese pampas grass (*Miscanthus sinensis*). The grassland is burnt intentionally every year to enhance its survival. Based on Editorial Committee of the history of Soni Village (1972), the grassland is likely to have been burnt intentionally for at least 100 years. Okame-ike mire is covered with bog flora dominated by reed grass (*Phragmites australis)*. Part of the mire contains a floating island consisting of reed grass roots.

3. Materials and Methods

A sediment core (length, 2.4 m) was recovered from the mire (at the floating island; 34°31′09″N, 136°09′48″E) at a water depth of 90 cm. The sediments in the core consist mainly of peat and peaty clay, although depths between 189 and 240 cm contain sand layers interbedded with peat and peaty clay (Fig. 2). Volcanic glass occurs at 216–223 cm depth. The shape of the volcanic glass is dominantly H type and lesser C type (according to the classification scheme proposed by Yoshikawa, 1976), the refractive index is 1.508–1.514, and some of the glass is brown. Based on these features, the volcanic glass is identified as K-Ah volcanic glass that was dispersed at 7,300 cal BP (Machida and Arai, 1992). Five samples (seeds, leaves, and charcoal fragments) from the core sediment were dated by radiocarbon methods (Table 1). Radiocarbon dates were calibrated to calendar years using the program Calib Rev 6.0 (http://intcal.qub.ac.uk/) and the IntCal09 calibration dataset (Reimer et al., 2009). Based on these ages, the sediments analyzed in this study were deposited from approximately 7500 cal BP to the present. The age-depth curve was drawn from these ages (Fig. 3). Based on the curve, the sedimentation rate is 0.33 mm/y below 157 cm depth, 1.73 mm/y at 123-157 cm depth, 0.06 mm/y at 123-98 cm depth and 1.11 mm/y above 98 cm depth.

For pollen analysis, 37 sediment samples (1 cm^3) were taken from selected levels in the core and prepared using standard techniques (Faegri et al., 1989). All fossil pollen grains and spores extracted from the samples were preserved in glass bottles with silicon oil. At least 350 arboreal pollen grains were counted for each level. The percentage of each taxon in pollen diagrams was calculated based on the sum of arboreal pollen. *Alnus* was excluded from analysis because of the large amount derived from *Alnus* thickets, which are abundant in bogs within Japan.

For analysis of macroscopic charcoal, sediment subsamples of 1 cm^3, collected from a 1 cm thickness of core, were taken at intervals of less than 3 cm between 5 and 232 cm depth. To extract charcoal fragments from the sediments, 3% H_2O_2 was first added to each sample for 24 hrs to disperse particles, and digest and bleach organic matter. The samples were then gently washed through a series of nested sieves (mesh sizes: 125 μm, 250 μm, and 1 mm) to divide the sample into 125–250 μm, 250 μm–1 mm, and > 1 mm fractions. The residue was collected and placed in a Petri dish. Charcoal fragments, which were recognized as black, opaque, angular fragments showing cellular features, were identified and counted under a stereomicroscope (Fig. 4). All charcoal fragments of 125–250 μm and 250 μm–1 mm in each sediment subsample of 1 cm^3 were counted and the number of charcoal fragments was treated as charcoal abundances (particles/cm^3). Charcoal accumulation rates (particles/cm^2 y) were determined by multiplying abundances (particles/cm^3) by sedimentation rate (cm/y).

Abies leaves were observed by eye in the sediments; consequently, the number of leaves in each subsample was counted using a stereomicroscope. Sediment samples (7 cm^3) collected at intervals of ~10 cm in the core were gently washed through a series of nested sieves (mesh sizes of 250 μm, 500 μm, and 1 mm). The numerical density of leaves was then counted in the residue for each size fraction (number of leaves/7 cm^3). Both whole leaves and leaf fragments were counted: a whole leaf was counted as 1 leaf, less than 50% leaf loss was counted as 0.7 of a leaf, and more than 50% leaf loss was counted as 0.3 of a leaf. The total number of leaves was then calculated for each sediment sample.

4. Results

4. 1. Pollen

The results of pollen analysis are shown in Fig. 5. The pollen diagram was divided visually into four local pollen assemblage zones (OKM-1, OKM-2, OKM-3, and OKM-4) based on changes in the proportions of arboreal and herbaceous taxa.

4. 1. 1. Zone OKM-1

Zone OKM-1 is characterized by a predominance of deciduous broad-leaved tree pollen, such as *Quercus* subgenus *Lepidobalanus* (27–32%), *Fagus crenata* (2–8%), and *Fagus japonica* (3–9%). *Abies* pollen make up 4–13% of the total count, while *Cryptomeria* and Cupressaceae type pollen make up 8–19% and 10–17%, respectively. In terms of herbaceous pollen and spores, Gramineae are abundant in this zone (10–26%). The proportion of *Isoetes* spores is very high in the upper part of the zone (9–42%).

4. 1. 2. Zone OKM-2

Zone OKM-2 is characterized by an upward increase in the abundance of *Castanea*/*Castanopsis* pollen in the lower zone (from 11% to 34%) and a decrease in the upper zone (from 34% to 8%). *Quercus* subgenus *Lepidobalanus* was relatively rare in the upper part of the zone (8–13%), but more abundant in the lower part (23–24%). *Quercus* subgenus *Cyclobalanopsis* shows a gradual upward increase in abundance (from 7% to 16%). *Abies* pollen makes up 4–11% of the total count, and *Cryptomeria* and Cupressaceae type pollen make up 8–15% and 9–15%, respectively. Regarding herbaceous pollen and spores, the proportion of Gramineae pollen shows a gradual upward reduction in this zone (from 11% to 3%). Cyperaseae pollen are abundant in the upper part of the zone (19–34%).

4. 1. 3. Zone OKM-3

Zone OKM-3 is characterized by a predominance of evergreen broad-leaved tree pollen of *Quercus* subgenus *Cyclobalanopsis* (15–23%) and a lack of herbaceous pollen and spores.
Quercus subgenus *Lepidobalanus* (7–17%), *Fagus crenata* (6–11%), and *Fagus japonica* (7–12%) pollen are abundant relative to zone OKM-2. The abundance of *Abies* shows little variation in this zone (6–17%). *Cryptomeria* (6–14%) and Cupressaceae type (6–12%) pollen are relatively abundant in this zone, although *Cryptomeria* is rare in the upper part. Herbaceous pollen and spores are generally rare throughout the zone (e.g., Gramineae, 2–10%), except for Cyperaseae (3–12%).

4. 1. 4. Zone OKM-4

Zone OKM-4 is characterized by an upward increase in the abundance of *Pinus* pollen (from 1% to 41%) and large amounts of herbaceous pollen and monolete spores. *Quercus* subgenus *Cyclobalanopsis* is abundant in the lower part of the zone (14–25%) but relatively rare in the upper part (7–9%). *Quercus* subgenus *Lepidobalanus* is generally abundant (10–24%) relative to zones OKM-2 and OKM-3. The lower part of the zone contains a greater proportion of *Abies* pollen (6–11%) than in the upper part (1–3%). Cupressaceae type pollen occurs in small amounts (2–8%) and *Cryptomeria* pollen shows an upward increased in abundance from 3% to 13%. Gramineae pollen are abundant (10–32%) throughout the zone. The abundance of monolete spores shows an abrupt increase in the lowermost part of the zone, and these spores occur in relatively large numbers throughout the zone (4–58%).

4. 2. Macroscopic charcoal

Given that very few charcoal fragments was > 1 mm in size, fragments were counted in the 125–250 μm and 250 μm–1 mm fractions. Charcoal of 125 μm–1 mm in size was considered as macroscopic(Fig. 5). Charcoal abundance in each subsample was classified as either high abundance (> 100 particles/cm^3) or low abundance (< 100 particles/cm^3), which correspond to high accumulation rate (> 10 particles/cm^2 y) and low accumulation rate (< 10 particles/cm^2 y) respectively, except for in 100-108 cm depth. The different trend of between charcoal concentrations and charcoal accumulation rates in 100-108 cm depth is due to the exceptional small sedimentation rate (0.06 mm/ y) at 98-123 cm depth. Charcoal abundance is probably more reliable to estimate fire frequency than charcoal accumulation rate, influenced largely by the exceptional sedimentation rate in the zone. Consequently, fire history was constructed from charcoal concentrations. High abundances were recognized at 217–226 cm depth (310–887 particles/cm^3) and above 108 cm depth (149–5304 particles/cm^3). In five samples, the interval at 87–96 cm contained the highest abundances (1296–5304 particles/cm^3). High abundances are found at depths greater than 108 cm in pollen zone OKM-4. Low abundances are found at depths of 227–232 cm (1–68 particles/cm^3) and 108–217 cm (0–77 particles/cm^3) in zones OKM-2 and OKM-3 respectively.

4. 3. Abies leaves

Abies leaves were found at 64 cm depth and at 112–190 cm depth (except for 165 cm depth) (Fig. 5). The highest number density was found between 190 and 112 cm depth (1–7 leaves per 7 cm^3 of sediment).

5. Discussion

5. 1. Vegetation trends mainly related to climate change prior to ~1500 cal BP

The trends in vegetation since 7500 to 1500 cal BP on the Soni Plateau and in adjacent areas inferred from pollen record are consistent with the general trends in vegetation observed on the Pacific side of Kinki District, Central Japan (e.g., Takahara, 1998) reconstructed from palynological data, which reflect the effects of post-glacial climate change. Therefore, the reconstructed changes in vegetation from pollen record on and around the Soni Plateau, especially in adjacent areas, between 7500 and 1500 cal BP would mainly have resulted from regional climate change.

Between 7500 and 6500 cal BP (OKM-1), deciduous broadleaf trees of *Quercus* subgenus *Lepidobalanus*, *Carpinus*/*Ostrya*, *Fagus crenata* and *Fagus japonica* grew with *Abies* and *Cryptomeria* in the area, which reflects cool-temperate climatic conditions.

Between 6500 and 5500 cal BP (OKM-2), evergreen broadleaf trees of *Quercus* subgenus *Cyclobalanopsis* expanded significantly in the area under a warming trend during the early Holocene. In this initial period, the abundance of *Castanea*/*Castanopsis* and pollen shows an abrupt increase and became predominant. Six *Castanea*/*Castanopsis* pollen grains were observed at 194 cm depth (OKM-2) by SEM, all of which were identified as *Castanea* pollen based on the classification criteria proposed by Miyoshi (1982). This finding suggests that most of the *Castanea*/*Castanopsis* pollen in OKM-2 are *Castanea*, which has entomophilous flowers that generally deposit pollen close to the source. The pollen record at Ikenohira Bog, located 2 km northeast of the Soni Plateau (Matsuoka et al., 1983), contains few or no *Castanea* pollen during this period. This finding indicates that *Castanea* trees occurred locally, probably only on the Soni Plateau or in adjacent areas.

Between 5500 and 1500 cal BP (OKM-3), evergreen broadleaf trees of *Q* subgenus *Cyclobalanopsis* were developed with deciduous broadleaf trees of *Q* subgenus *Lepidobalanus*, *F crenata* and *F japonica* and conifer trees of *Abies* and *Cryptomeria* in the area. It has been considered that evergreen broadleaf forest developed in the Kinki Region during this period after the Holocene Climate Optimum, possibly due to precipitation increased since 6000 cal BP (e.g., Takahara, 1998) .

5. 2. Intentional fires and vegetation change since ~1500 cal BP

An analysis of air photographs of the Soni Plateau taken in 1945, 1963, 1970, and 2001 (available at the Japanese Geographical Survey Institute web site, http://archive.gsi.go.jp/airphoto/) reveals that grassland has been maintained in this area for at least the past 65 years. According to Editorial Committee of the History of Soni Village (1972), until ~100 years ago, each settlement near the Soni Plateau had maintained grassland areas, carrying out annual burnings. The grasses were gathered and used for fertilizer until ~100 years ago. The grassland in the Soni Plateau is probably one of such grassland areas and has been maintained until now. Although the ages of the uppermost sediments recovered in this study are unclear, based on the age-depth curve (Fig.3) radiocarbon age data indicate that they were deposited within the past 100–200 years. The documents cited above indicate that grassland had already developed on the Soni Plateau at this time in response to intentional fires. Furthermore, considering that the grassland was maintained to use for fertilizer, annual burnings were presumably carried out for at least several hundreds years.

Because macroscopic charcoal fragments (> 100 μm in size) are not transported far from the source before settling (e.g., Whitlock and Larsen, 2001), most of the macroscopic charcoal within sediments from the Okame-ike mire are likely to have been derived from fires on the Soni Plateau. Charcoal abundances of 110–229 particles/cm^3 (high charcoal abundance) in sediments at 5–15 cm depth in the analyzed core probably correspond to fires on the plateau at approximately annual intervals. Above 108 cm depth (OKM-4, after possibly 1500 cal BP, dated back to at least 1000 cal BP; see below), the sediments contain high charcoal abundances (149–5304 particles/cm^3), equal to or greater than the abundances in the uppermost sediments, which correspond to annual fire events. This finding suggests that fire has occurred approximately every year since possibly ~1500 cal BP, probably representing intentional burning.

In terms of the pollen record in OKM-4, the proportions of herbaceous pollen such as Gramineae and monolete spores are extremely high relative to those at other levels, suggesting that grasslands have occurred in the area since ~1500 cal BP. The increasing trends in macroscopic charcoal fragments, herbaceous pollen, and spores, combined with a decrease in *Abies* pollen and an absence of *Abies* leaves (except for a piece of leaf at 64 cm depth in sediments corresponding to OKM-4) suggest that *Abies* trees, which occurred between 5500 and 1500 cal BP, disappeared almost entirely from the plateau once intentional fires became commonplace.

Based on radiocarbon age data, charcoal fragments of > 250 μm in size in sediments at 96–98 cm depth are 924–1057 cal BP (1060 ± 40 BP) in age. These depths are 10 cm shallower than the lowest level of the interval of high charcoal abundance (108 cm), which continues to the uppermost sediments. The ages of charcoal fragments indicate that initial fires probably occurred prior to 1000 cal BP. Prior to 1000 cal BP (possibly dated back to ~1500 cal BP), initial fires or possibly logging disturbed the forest on the plateau, resulting in the development of grassland (Gramineae and other taxa). Then, periodic intentional fires (approximately every year) have prevented tree development and forest invading the plateau and the grassland have been maintained for at least 1000 years. Based on observations of the modern-day Soni Plateau, the grassland over the past 1000 years would have been dominated by *Miscanthus sinensis*. The differences in charcoal abundance at various levels above 108 cm in the core may reflect changes in the depositional environment (e.g., water extent, sedimentation rate, and size of the floating island).

Taking into account the environment of the Soni Plateau since 1000 cal BP, the increase in *Pinus* pollen (probably *Pinus densiflora*) in OKM-4 is expected to reflect vegetation change, mainly in areas adjacent to the

Soni Plateau. According to Takahara (1998), secondary forest of *P. densiflora* has expanded widely in mountainous areas since 700–1000 cal BP in the Kinki District, due to human-induced destruction of natural forest. After 1000 cal BP, the extent of secondary *Pinus* forest would have expanded in response to human disturbance of natural forest in areas adjacent to the Soni Plateau.

5. 3. Fire occurrence during a short interval at ~7,000 BP

Charcoal abundances in a narrow zone at 217–226 cm depth in the core (310–887 particles/cm^3) are similar to those in sediments deposited after 1000 cal BP, when intentional burning was practiced, probably indicating the occurrence of frequent fires during a short-period at ~7000 cal BP. In Japan, this interval corresponds to the Initial Jomon Period (10,000–7000 cal BP; belong to the Neolithic Period). One of the earliest human remains found around the Soni Plateau (at a site located 1 km southeast of the plateau) dates to the Initial Jomon Period (Editorial Committee of the History of Soni Village, 1972; Kashihara Archaeological Institute, Nara Prefecture, 1998). In addition, several remains dating to the Initial Jomon Period have been discovered in an area adjacent to the plateau, suggesting that the area was initially settled during this time (Editorial Committee of the History of Soni Village, 1972). The similarity in the timing of human settlement and fire occurrence on the plateau indicates that the fires occurred due to human activity during the Jomon Period. Given that the abundance of Gramineae pollen shows some increases at around the levels with abundant charcoal, it is likely that the forest was disturbed at those time and that grassland expanded on the plateau in response to intentional burning. The occurrence of episodic fires was possibly also related to the development of *Castanea* forest on the plateau, as Goto et al. (1996) reported that sprouts of *Castanea crenata* are more vigorous and grow more rapidly after a fire event than before.

6. Conclusion

Pollen and macroscopic charcoal fragments in mire sediments deposited since 7500 cal BP on the Soni Plateau, Central Japan, where intentional burning has helped to sustain grassland for at least the past 100 years, were examined. Until ~1500 cal BP except for a short period at ~7000 cal BP, forests of *Abies, Quercus*, and *Fagus* had developed under largely fire-free conditions in and around the plateau and vegetation transition has been influenced mainly by climate cahange. The occurrence of frequent fires during a short interval at ~7000 cal BP, probably due to human activity, possibly resulted in an expansion of grassland, whereas *Castanea* forest developed after the fire-prone period. Since ~1500 cal BP (at least since 1000 cal BP), periodic intentional fires have resulted in the development and maintenance (until the present day) on the plateau of grassland dominated by Gramineae.

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Figure captions

Fig. 1 Map showing the location of the sampling site. Map A shows location of Soni Plateau. Map B is part of the 1:5000 topographical map of Soni Village issued by the Soni Village Office, showing the sampling point.

Fig. 2 Lithological description of the sediment core analyzed in the present study.

Fig. 3 Age-depth model of Okame-ike Mire sediment core.

Fig. 4 Macroscopic charcoal fragments (arrow) extracted from the mire sediment (95-96 cm depth).

Fig. 5 Percentage pollen diagram for the Okameike Mire sediments on the Soni Plateau, also showing charcoal abundance, charcoal accumulation and number of *Abies* leaves. *No charcoal fragments (0 particle/cm^3), charcoal accumulation rate of less than 0.1 particles/cm^2 y or no leaves (0 leaves/ 7cm^3). Black dots indicate one charcoal fragment (1 particle/cm^3).

Table 1 Radiocarbon dates obtained for Okameike Mire sediments on the Soni Plateau. ^{14}C dates were calibrated to calendar years using the program Calib Rev 6.0 (http://intcal.qub.ac.uk/) and the IntCal09 calibration dataset (Reimer et al., 2009).

Sample depth (cm)	^{14}C date BP ±1σ	Cal BP year within 2σ error	Material	Code
16–17	390±20	332–505	seed	PLD-10069
33–34	385±20	331–505	seed	PLD-10070
96–98	1060±40	924–1057	charcoal fragments (> 250 μm in size)	Beta-228666
121.5–122.5	4410±40	4862–5273	leaves	Beta-228667
156–157	4590±25	5084–5445	leaves	PLD-11281

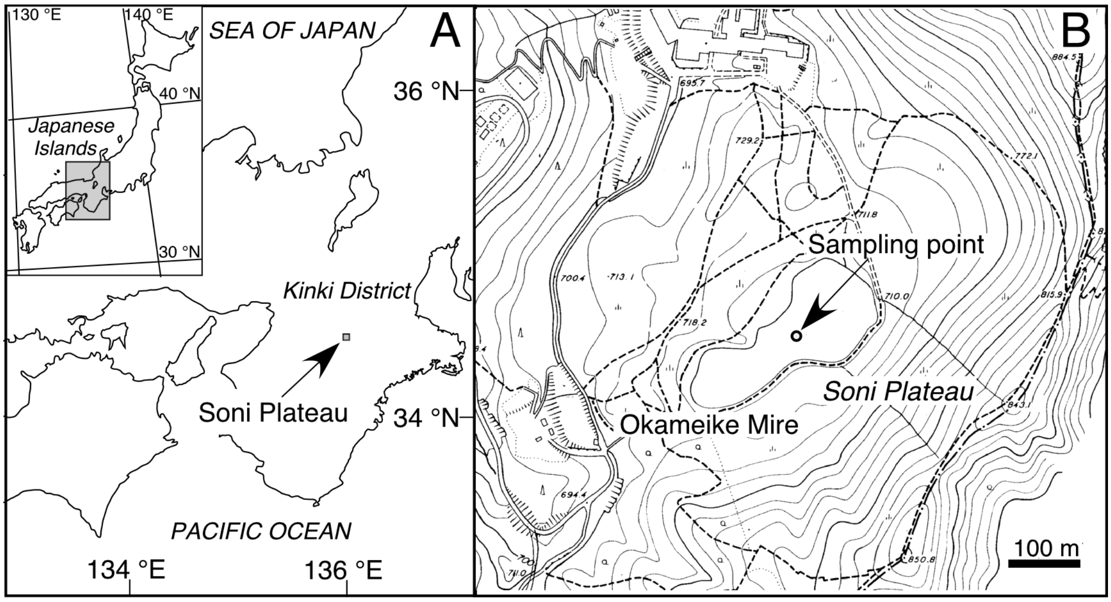
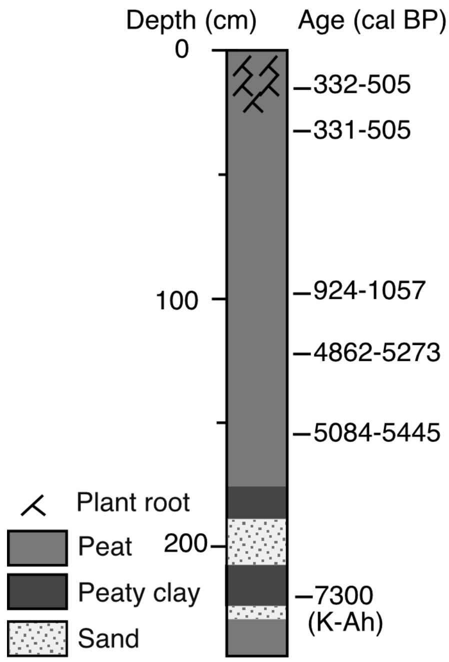
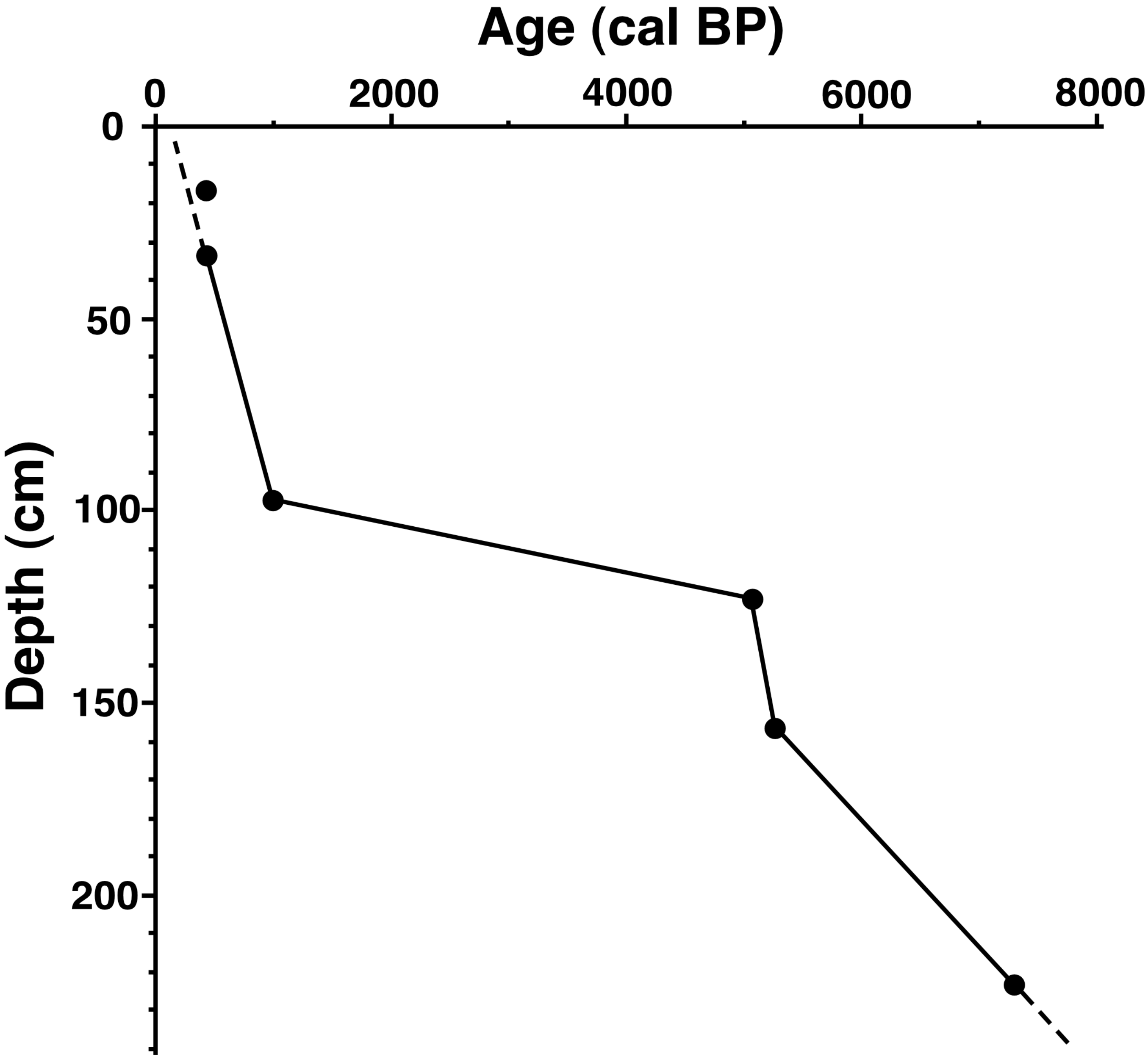
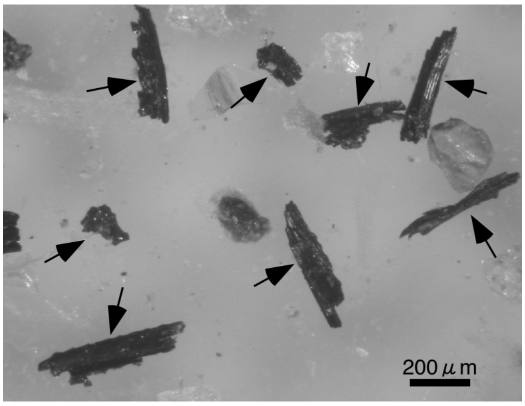


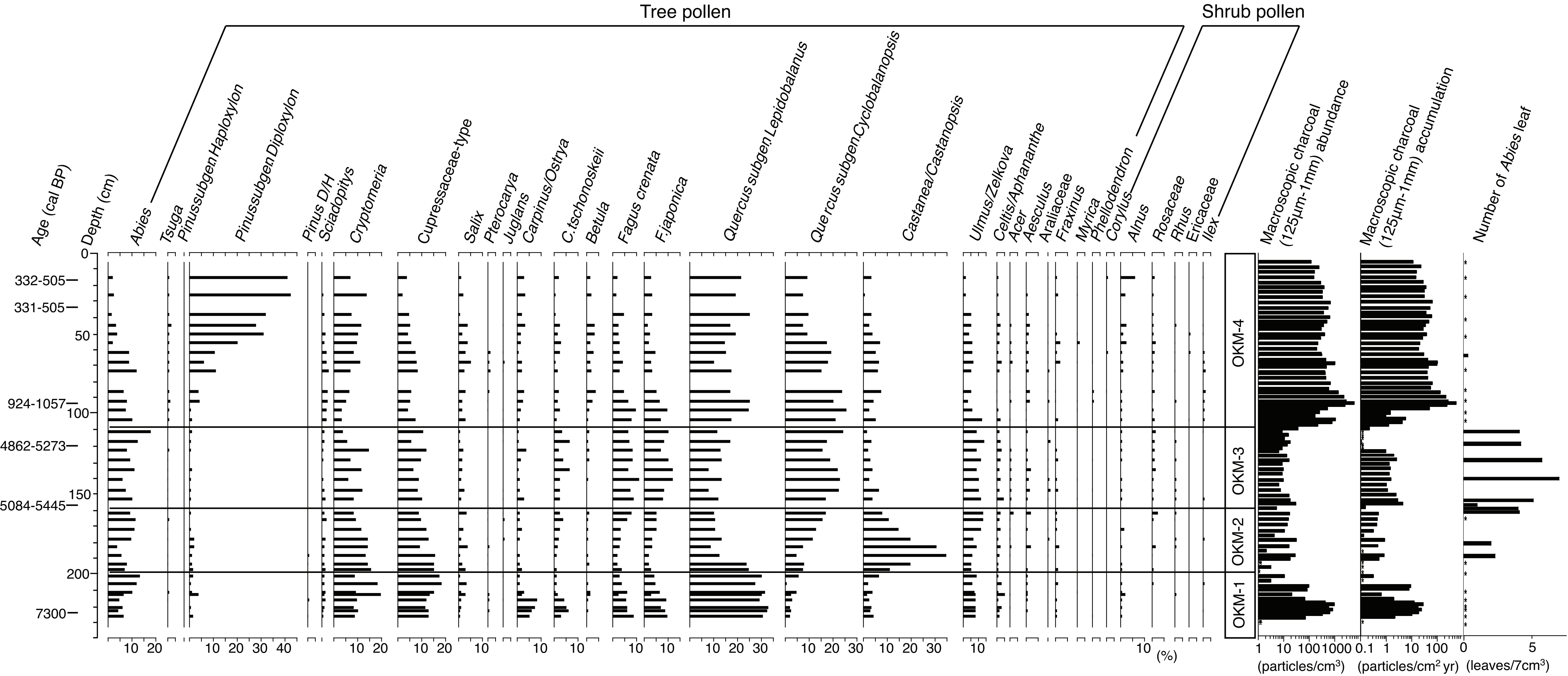
Fig. 1 (Inoue et al)

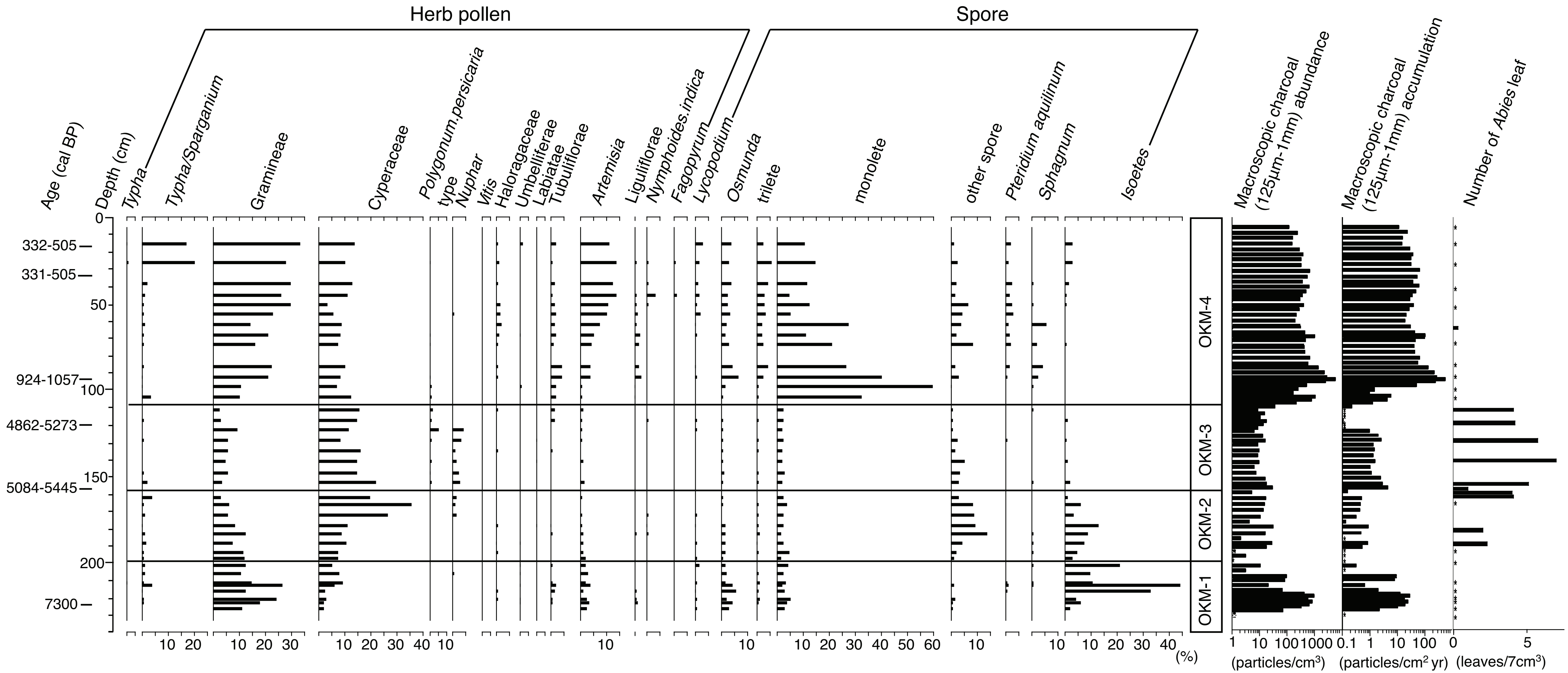


Depth (cm)
Age (cal BP)
0
100
200
332-505
331-505
924-1057
4862-5273
5084-5445
7300
(K-Ah)
Plant root
Peat
Peaty clay
Sand


Age (cal BP)
0
2000
4000
6000
8000
0
50
100
150
200
Depth (cm)


200 μm


Tree pollen
Shrub pollen
Age (cal BP)
Depth (cm)
Abies
Tsuga
Pinus subgen. Haploxylon
Pinus subgen. Diploxylon
Pinus D/H
Sciadopitys
Cryptomeria
Cupressaceae-type
Salix
Pterocarya
Juglans
Carpinus/Ostrya
C. tschonoskeii
Betula
Fagus crenata
F. japonica
Quercus subgen. Lepidobalanus
Quercus subgen. Cyclobalanopsis
Castanea/Castanopsis
Ulmus/Zelkova
Celtis/Aphananthe
Acer
Aesculus
Araliaceae
Fraxinus
Myrica
Phellodendron
Corylus
Alnus
Rosaceae
Rhus
Ericaceae
Ilex
Macroscopic charcoal (125µm-1mm) abundance
Macroscopic charcoal (125µm-1mm) accumulation
Number of Abies leaf
332-505
331-505
924-1057
4862-5273
5084-5445
7300
OKM-4
OKM-3
OKM-2
OKM-1
(%)
(particles/cm3)
(particles/cm2 yr)
(leaves/7cm3)



Herb pollen
Spore
Age (cal BP)
Depth (cm)
Typha
Typha/Sparganium
Gramineae
Cyperaceae
Polygonum.persicaria type
Nuphar
Vitis
Haloragaceae
Umbelliferae
Labiatae
Tubuliflorae
Artemisia
Liguliflorae
Nymphoides.indica
Fagopyrum
Lycopodium
Osmunda
trilete
monolete
other spore
Pteridium aquilinum
Sphagnum
Isoetes
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