PALEOENVIRONMENT IN DAE-AM SAN HIGH MOOR IN THE KOREAN PENINSULA

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ABSTRACT. We discuss paleoenvironmental changes at the Dae-Am San high moor, located near the Demilitarized Zone at 38°N. This area has been reported to be the only high moor in the Korean peninsula. The ^{14}C age of the bottom sediment (75–80 cm in depth) at this site is about 1900 BP. Since the radiocarbon ages for the intervals at 50–55 cm and 75–80 cm were almost the same, we conclude that the deep layers (55–80 cm) in the high moor were all part of the original soil. Low organic C and N contents in the deeper layers support this inference. The 50–55-cm layer consists of sandy material with very low organic content, suggesting erosion from the surrounding area. The surface layer (0–5 cm) was measured as 190 BP, and the middle layer (30–35 cm) was 870 BP. The bulk sedimentation rate was estimated to be about 0.4 mm yr^{-1} for the 0–30-cm interval. The δ^{13}C value of organic carbon in the sediments fluctuated with depth. The δ^{13}C profile of the Dae-Am San high moor may be explained by climatic changes which occurred during the Little Ice Age and Medieval Warm Period.

INTRODUCTION

Terrestrial paleoenvironments can be reconstructed using sediment cores from lakes and swamps (e.g. Williams et al. 1997). The Dae-Am San Yong-Nup (high moor) on Dae-Am San Mountain is located near 38°N latitude, in the Demilitarized Zone (DMZ). This site is believed to be the only high moor in the Korean Peninsula. The paleoenvironmental reconstruction of this high moor reflects on the broader environmental changes which occurred in the Korean Peninsula during its formation. In this study, we analyzed the sediment carbon isotopic compositions from the Dae-Am San high moor and assessed possible environmental changes reflected in the record.

METHODS

Dae-Am San high moor (area = 3.15 ha) is located on the north-facing slope of Mount Dae-Am (128°07'E, 38°13'N) at an elevation between 1100 and 1200 m. Although at the deepest point the peat soil was deeper than 150 cm, the site where the samples were collected accumulated peat for less than 80 cm of its depth. Sediments were collected in 15 layers of 5-cm thickness from 0 to 80 cm depth, except for the 60–70-cm layer. Samples were air-dried and sieved with 500 and 250 µm mesh stainless steel sieves, and weighed to calculate the relative abundance (Figure 1). Three sizes of the sieved samples (< 250 µm, 250–500 µm, and >500 µm) were treated by a sealed-quartz-tube combustion method (Minagawa et al. 1984) for carbon and nitrogen isotope measurements. During the gas purification procedure, the organic carbon (Org. C) and total nitrogen (TN) contents were estimated from the barometric measurements of CO_2 and N_2 gases produced from the sample. Since the differences in Org. C, TN and isotope ratio among sizes were small, Org. C and TN contents and carbon isotope ratios for each layer were calculated from the size fractions using relative abundances. The ^{13}C isotopic compositions were measured with an isotope ratio mass spectrometer (MAT 252, Thermoquest, Ltd.). These isotopic ratios are expressed with δ notation (unit = ‰). The ^{14}C content was determined for the >500-µm fractions from five layers (0–5 cm, 30–35 cm, 45–50 cm, 55–60 cm, and 75–80 cm). The samples were treated using an acid-alkali-acid (AAA) treatment sequence of HCl (1.2N), NaOH solution (1.2 N), HCl (1.2N), to remove organic contaminants. The treated samples containing carbon of about 2 mg was combusted to CO_2 at 850 °C for 2 hr in a vacuum-sealed Vycor

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tube with CuO. The cryogenically purified CO_2 gas was reduced to graphite with hydrogen gas (Kitagawa et al. 1993). The graphite targets prepared from a sample and a standard of NBS oxalic acid (RM-49), were used for ^{14}C analysis with a Tandetron Accelerator Mass Spectrometer at the Center for Chronological Research in Nagoya University. The isotopic fractionation was corrected using the sample δ^{13}C value in evaluation of the ^{14}C age.

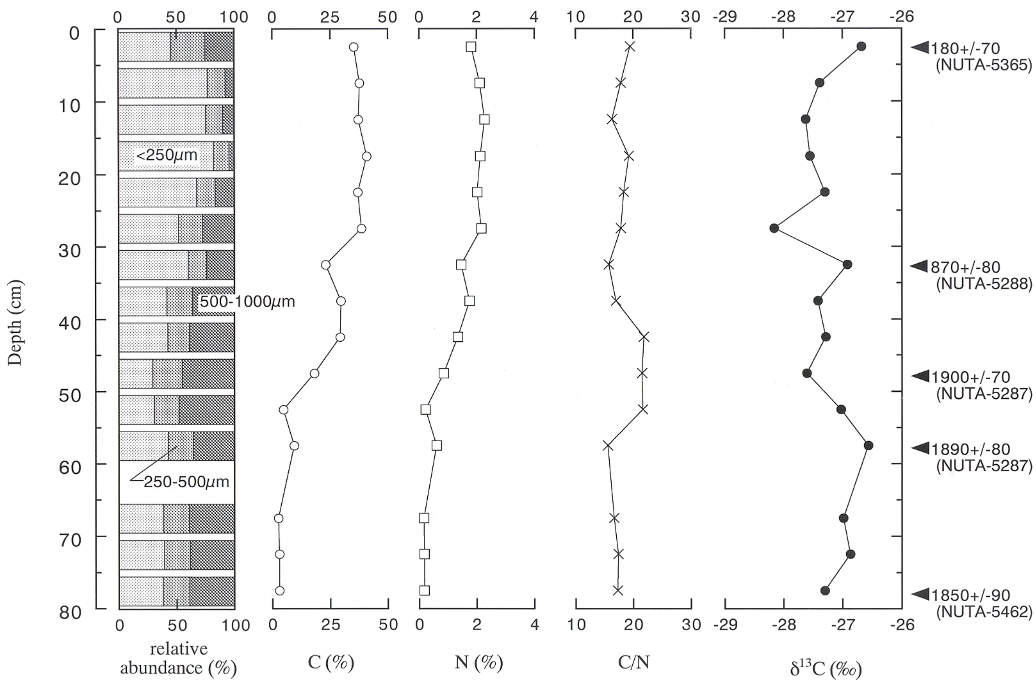

Figure 1 Vertical distributions of relative abundance of size fractions (bars), organic carbon (open circle) and total nitrogen contents (open square), C/N ratio (X), and carbon (closed circle) isotope ratios of the sediments in Dae-Am San high moor, Korea. Measured ^{14}C ages (yr BP ± 1σ) were indicated at the right-hand side.

RESULTS

Organic carbon (Org. C) and total nitrogen (TN) contents in the sediments varied with depth (Figure 1). Both contents were higher in the surface layers (<30 cm). Org. C and TN ranged from 35 to 41% and from 1.8 to 2.3%, respectively. From 30 to 55 cm, they decreased sharply, with a small maximum in the 35–40 cm layer. There was also a small maximum both in carbon and nitrogen contents in the 55–60 cm layer. Organic contents between 60 and 80 cm were as low as 3% carbon and 0.2% nitrogen. In spite of the large variations in Org. C and TN, the weight to weight ratio between them (C/N) was rather constant (average, 18.3 ± 2.1, n = 15, Figure 1).

The δ^{13}C values of the bulk sediment ranged from –28.2 to –26.6‰, with minima (< –27.5‰) at 10–15 cm, 25–30 cm, and 45–50 cm layers (Figure 1). The deepest layer also showed a low δ^{13}C value.

Table 1 shows the results of the ^{14}C dating. The 0–5 cm and 30–35 cm layers exhibited the age of 180 ± 70 BP and 870 ± 80 BP, respectively. All three layers deeper than 45 cm showed a similar age of about 1900 BP.

Table 1 Radiocarbon ages of Dae-Am Sang high moor sediments

Layer (cm)	^{14}C age (BP)	Calibrated age[a] Cal AD	Probability	Lab code (NUTA-)
0–5	180 ± 70	1654–1697	0.201	5365
		1725–1815	0.482	
		1841–1874	0.160	
		1918–1944	0.157	
30–35	870 ± 80	1046–1091	0.296	5288
		1119–1139	0.117	
		1154–1240	0.587	
45–50	1900 ± 70	31–37	0.055	5287
		51–179	0.836	
		189–213	0.109	
55–60	1890 ± 80	55–230	1.000	5364
75–80	1850 ± 90	64–257	0.929	5462
		300–321	0.071	

[a]The ^{14}C ages were converted to calibrated ages using the INTCAL98 program, Calib 4.1.2 downloaded from the website of the University of Washington Quaternary Isotope Lab. URL: <http://depts.washington.edu/qil/dloadcalib/>. Accessed 9 Feb 2000.

DISCUSSION

Since the Org. C contents at the 55–60 cm layer was as high as 10%, the swamp might have been initiated at the 50-cm depth, which corresponds to about 1900 BP. Assuming that the accumulation rate of peat between layers was constant, the bulk sedimentation rate was about 0.4 mm yr^{-1} for the surface 35-cm layers, and about 0.15 mm yr^{-1} for the 35–50-cm layers. Estimated ages for each layer are shown in Figure 2. The range of bulk sedimentation rate is similar to the sedimentation rate in the Ozegahara wetland in Japan (Minomo et al. 1997).

Plant $\delta^{13}C$ values reflect a changing ecosystem through time. In Dae-Am San high moor, the vegetation changed from sedge to sphagnum during swamp development (Environmental Agency, Korea, 1988). Some of the observed $\delta^{13}C$ variations shown in Figure 1 may be due to vegetation changes (White et al. 1994). Another factor affecting the $\delta^{13}C$ value of peat is the selective decomposition of organic carbon. Since lignin has a lower $\delta^{13}C$ value than polysaccharides, the preferential loss of polysaccharides, such as hemicellulose and cellulose, may cause a decrease in bulk organic carbon $\delta^{13}C$ values (Benner et al. 1987). Minomo et al. (1997) suggested that the low $\delta^{13}C$ value in the deep layer of Ozegahara peat sediment indicated an increase in lignin content. The analysis of environmental changes in a swamp from the isotopic viewpoint, thus, is complicated. However, the vertical changes in the isotopic compositions obtained here would indicate some environmental changes in the Dae-Am San high moor and also in the Korean Peninsula, because the $\delta^{13}C$ value fluctuated with depth.

Recently, much attention has been paid to the Little Ice Age (LIA) and Medieval Warm Period (MWP). The paleoclimate changes in the last 2000 to 3000 yr have been studied in ice cores and marine sediments (e.g. Kreutz et al. 1997; Keigwin 1996). The $\delta^{13}C$ records preserved in tree rings of Japanese cedar in Yakushima Island indicated a relatively cold climate from AD 610 to 700 and from AD 1580 to 1700 (Kitagawa and Matsumoto 1995). The latter period was related to LIA. During AD 700–1200 (corresponding to MWP), about 1 °C increase in average temperature was estimated from tree ring analyses (Kitagawa and Matsumoto 1995).

Upward increases in the $\delta^{13}C$ values (Figure 1) from 50 to 35 cm and from 15 to 0 cm suggest increasing temperatures and/or dry conditions. During these periods, the Dae-Am San high moor developed. The ages of the layers, where the $\delta^{13}C$ minima of sedimentary organic matter were found in Dae-Am San high moor (Figure 1), correspond to about 400, 750, and 1200 yr ago (Figure 2). The maximum $\delta^{13}C$ values occurred in the layer with an estimated age of about 900 BP. The sedimentary $\delta^{13}C$ records in Dae-Am San high moor suggest that the climate in the Korean Peninsula was cold in the LIA and about 1200 yr ago, and warm during the MWP. This suggests that the main cause of $\delta^{13}C$ variations could have been initiated by changes in air temperature. If this is true then the Little Ice Age and Medieval Warm Period are global events, affecting the swamp environment in the Korean Peninsula. However, water conditions must also be considered. Since there is no information on cold climate about 750 yr ago, the abrupt decrease in the $\delta^{13}C$ value in the 25–30-cm depth range could indicate a change in water supply at that time.

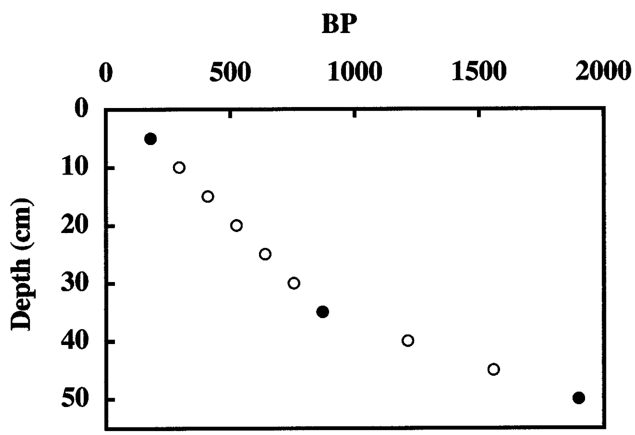

Figure 2 Estimated ages for the layers from 0 to 50 cm depth. The constant accumulation rates were assumed between layers (closed circles) of which radiocarbon age were measured.

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