A NEW ^{14}C DATA SET OF THE PY608W-PC SEDIMENT CORE FROM LAKE PUMOYUM CO (SOUTHEASTERN TIBETAN PLATEAU) OVER THE LAST 19 KYR

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ABSTRACT. A new continuous sediment core (PY608W-PC; 3.8 m length) for reconstruction of climatic and environmental changes in the southeastern Tibetan Plateau was taken from the eastern part of Lake Pumoyum Co in August 2006. Sediment layers of the lower part of PY608W-PC (380–300 cm depth) were composed mainly of relatively large plant residues (up to ~3 cm in length) with an admixture of fine sand and sandy silt. The large plant residues disappeared at ~300–290 cm depth in core PY608W-PC and were replaced by silt-silty clay. The large plant residues from the lower part of PY608W-PC could be aquatic, because the plant residues were extremely enriched in ^{13}C (up to –3.0‰, –5.6 ± 2.3‰ on average). On the other hand, the plant residue concentrates (PRC fractions) from the upper part of the core (290–0 cm in depth) could be terrestrial C_3 plants ($\delta^{13}C$ = –21.8 ± 1.7‰ on average). Radiocarbon dating was performed on the large plant residues and PRC fractions from the PY608W-PC sediment core, which represented the chronology from ~19,000 cal BP to present.

INTRODUCTION

The Tibetan Plateau is highly sensitive to monsoon variability because it is near the limit of the Asian monsoonal influence (Shi 2002; Zhang et al. 2006). Therefore, paleoclimatic and environmental records from the Tibetan Plateau provide important clues for understanding the Asian climate system. At present, only a few continuous climate records over the ~20 cal ka BP have been reported for the Tibetan Plateau (R Wang et al. 2002; Thompson et al. 2006), and, in particular, no detailed record of late Quaternary environmental changes in the southeastern part on the plateau is available.

Lake Pumoyum Co is a freshwater lake formed by fault action on the southeastern Tibetan Plateau (28°34′N, 90°24′E; ~5020 m asl; lake surface area 281 km^2; maximum water depth ~65 m). Limnological and geological investigations of Lake Pumoyum Co were performed during the 2001–2006 China-Japan Scientific Research expeditions (Mitamura et al. 2003; Nishimura et al. 2003; Murakami et al. 2007; J Wang et al. 2009). During these expeditions, salinity and pH of the lake water were 1.9 g/L and 8.3–8.7, respectively. The Jiaqu River is the largest river flowing into Lake Pumoyum Co (72% of the inflow, Figure 1), and it forms vast wetlands on the western side of the lake. The watershed area of Pumoyum Co is ~1700 km^2.

Lake sediment cores from the southeastern Tibetan Plateau provide novel and important clues that can reveal variations in both the past environment and biological activities. Radiocarbon analysis based on accelerator mass spectrometry (AMS) is a widely used and accepted dating method for the last ~50,000 yr in sediment cores (Nakamura et al. 2003). Watanabe et al. (2008) has reported preliminary ^{14}C dating results of plant residues in the PY104PC sediment core from the northeastern part of Lake Pumoyum Co (28°33′56″N, 90°28′59″E; 46.5 m water depth).

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Proceedings of the 20th International Radiocarbon Conference, edited by A J T Jull
RADIOCARBON, Vol 52, Nr 2–3, 2010, p 1435–1442

https://doi.org/10.1017/S0033822200046518 Published online by Cambridge University Press

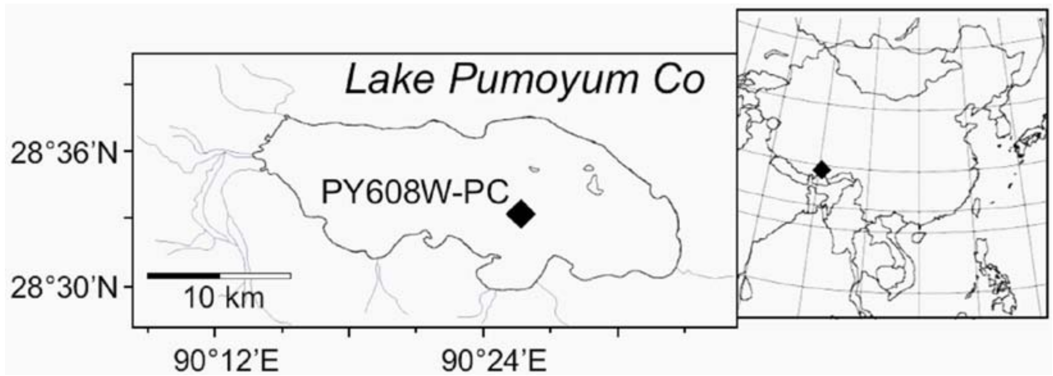

Figure 1 Map showing the location of Lake Pumoyum Co on the southeastern Tibetan Plateau, and the coring site (PY608W-PC).

A new continuous sediment core (PY608W-PC; 3.8 m core length) for reconstruction of climatic changes in the area was taken from the eastern part of Lake Pumoyum Co. The main objective of our study was to evaluate the resulting suite of 47 new AMS ^{14}C ages to establish a chronological framework for the PY608W-PC sediment core. In this study, fine (>125 μm) plant remains from the sediment layers of the core from Lake Pumoyum Co were concentrated by wet-sieving and picked out for dating in order to preclude an old carbon effect. Because stable carbon isotope ratios ($\delta^{13}C$ values) have proved to be useful for deducing the sources of plant fragments in lake sediments, we carried out both high-time-resolution ^{14}C dating and $\delta^{13}C$ measurements of plant residues from the sediment core.

SAMPLES AND ANALYTICAL METHODS

A 3.8 m-long piston core (PY608W-PC) was obtained from Lake Pumoyum Co in 2006 (28°33′05′′N, 90°25′42′′E; 51.7 m depth, Figure 1). Sediment samples were taken at 1-cm intervals, and their outer rims were removed to avoid contamination. Sediment layers of the lower part of PY608W-PC (380–300 cm in depth) were composed mainly of relatively large plant residues (up to ~3 cm in length, Figure 2) with an admixture of fine sand and sandy silt. The large plant residues quickly disappeared between 300 and 290 cm core depth and were replaced by silty clay and silt. The fine plant fragments in the upper part (300–0 cm in depth) of PY608W-PC were concentrated by wet-sieving, and then picked out with a tapering pipette (>125 μm, plant residue concentrates; PRC). The large plant residues in the lower part (380–300 cm in depth) were picked out by tweezers after wet-sieving of the sediment samples.

After sonication with pure H_2O to remove adhering contaminants (sediment particles), the plant residues and PRC fractions were cleaned by the acid-alkali-acid procedure using 1.2M HCl and 1.2M NaOH (AAA treatment, after Nakamura et al. 2003). The plant residues and PRC fractions remaining after the AAA treatment were combusted at 650 °C with CuO and Ag wires, and the resultant CO_2 was purified in a vacuum line. For ^{14}C dating of total organic carbon (TOC) from PY608W-PC, discrete sediment samples were dried and powdered and then treated with 1.2M HCl to remove carbonate. The decalcified sediment samples were combusted and changed to CO_2.

The purified CO_2 was reduced to graphite with an iron catalyst and hydrogen at 650 °C for 6 hr. ^{14}C measurements were performed by the AMS system (Model 4130-AMS, High Voltage Engineering Europe) at the Center for Chronological Research (CCR), Nagoya University. Conventional ^{14}C

Figure 2 Photograph of aquatic plant residue in the PY608W-PC sediment core (369 cm core depth) from Lake Pumoyum Co.

ages were then converted to calendar years using the IntCal04 data set (Reimer et al. 2004). δ^{13}C analyses of the plant residues and PRC fractions were carried out using an isotope ratio mass spectrometer (IRMS) (MAT-252, ThermoFinnigan) by a conventional dual-inlet system with cracking tubes. δ^{13}C values were expressed as per mil (‰) relative to Peedee belemnite (PDB). Standard deviations of the δ^{13}C measurements for an organic compound standard (oxalic acid) were generally less than ±0.1‰.

RESULTS AND DISCUSSION

Conventional ^{14}C Ages and Sources of Plant Residues in the PY608W-PC Sediment Core

In the lower layers of PY608W-PC (380–300 cm depth), conventional ^{14}C ages of the plant residues ranged from 16.0 to 13.0 ^{14}C ka BP (Table 1, Figure 3a). The plant residues in the lower layers of PY608W-PC were extremely enriched in ^{13}C (δ^{13}C = –3.0‰ to –10.3‰, –5.6 ± 2.3‰ on average, Figure 3b). These heavy isotope compositions clearly differed from those of living terrestrial plants around the lake (δ^{13}C = –23.9‰ to –28.1‰; Watanabe et al. 2008) and agreed well with those of living aquatic plants (Potamogetonaceae) in Lake Pumoyum Co (δ^{13}C = –4.7‰ to –6.7‰; 1–17 m water depth; Watanabe et al. 2008). Therefore, the large plant residues (up to ~3 cm in length) from the 380–300 cm depth could be aquatic. Smith and Walker (1980) reported ^{13}C-enrichment of macrophytes grown in culture experiments, and Morrill et al. (2006) reported ^{13}C-enrichment of macrophytes in a freshwater lake in the central Tibetan Plateau (δ^{13}C = up to about –5‰). The extremely heavy stable carbon isotope ratios of the Potamogetonaceae in Lake Pumoyum Co may be due to carbon fixation in a semi-closed system with limited dissolved inorganic carbon content.

δ^{13}C values of the plant residue concentrate (PRC) fractions from the upper part (300–0 cm depth) varied from –20.5‰ to –23.0‰ (–21.8 ± 1.7‰ on average, Table 1, Figure 3b) except for that in sediments from 293–292 cm depth in core PY608W-PC. These δ^{13}C values are typical of those of C_3 plants (–32‰ to –20‰; Schwarz and Redman 1987), indicating that the PRC fractions in the

Table 1 δ^{13}C values, conventional ^{14}C ages, and calibrated ages for core PY608W-PC.

Core depth (cm)	δ^{13}C$_{organic}$ (‰, PDB)	Conventional ^{14}C age (BP, ±1 σ)	Calibrated age (cal BP, 1 σ)	Lab code (NUTA2-)
PY608W-PC				
PRC fraction[a]				
1.0–3.9	–22.0	1198 ± 29	1076–1170	12725
8.7–12.6		3860 ± 47	4184–4406	13230
18.3–22.3		4448 ± 72	4965–5281	13227
28.9–33.9	–22.5	5464 ± 214	5991–6465	13228
33.7–38.6	–22.6	4002 ± 30	4426–4516	13972
38.6–41.5		4503 ± 59	5052–5289	12726
48.3–53.2		5833 ± 291	6314–6973	13247
57.9–62.9		5883 ± 62	6639–6783	13229
67.5–73.5		5698 ± 58	6409–6551	13232
77.2–83.1		6534 ± 86	7331–7560	13233
87.9–92.8		6747 ± 70	7567–7669	13234
101.6–108.6	–23.0	8126 ± 491	8421–9543	13235
116.5–122.4		7835 ± 110	8458–8931	13236
126.3–133.3		8686 ± 154	9526–10109	13237
164.9–169.9		7857 ± 83	8544–8932	13238
171.8–178.8	–22.1	8529 ± 80	9454–9555	13240
181.7–187.7		8511 ± 122	9320–9652	13249
188.7–195.6		7774 ± 84	8446–8631	13250
198.6–204.6		8308 ± 93	9140–9440	13241
207.6–214.6		8757 ± 99	9561–9907	13242
216.6–223.6		8748 ± 103	9560–9901	13243
226.6–231.6		8225 ± 95	9031–9300	13244
234.6–237.6	–22.5	9467 ± 99	10,574–11,068	12730
238.6–241.6	–21.2	9883 ± 131	11,186–11,608	12731
248.6–251.6	–22.7	9480 ± 69	10,589–11,065	12732
257.6–260.6	–23.0	9970 ± 54	11,269–11,600	12733
266.6–269.6	–22.5	10,652 ± 65	12,668–12,803	12734
278.6–281.6	–22.0	10,742 ± 41	12,779–12,834	12735
281.6–284.6	–20.5	10,996 ± 67	12,866–12,977	12738
291.7–292.7	–16.7	13,110 ± 89	15,296–15,681	12739
Aquatic plant residues				
301.2–302.3	–6.7	13,007 ± 48	15,204–15,496	12740
304.4–306.5		14,527 ± 65	17,299–17,755	12136
306.8–309.7	–3.8	14,969 ± 49	18,096–18,488	13973
309.7–310.7	–5.9	13,945 ± 67	16,411–16,826	12752
310.8–312.8	–6.5	14,205 ± 47	16,746–17,148	13974
320.3–321.3	–6.8	15,856 ± 64	18,953–19,101	12753
321.4–323.4	–8.0	15,990 ± 52	19,057–19,243	13975
325.6–327.7	–10.3	15,538 ± 138	18,742–18,925	12754
327.7–330.7	–8.3	15,724 ± 49	18,895–18,986	13976
336.2–337.2	–4.5	14,802 ± 57	17,796–18,082	12755
336.2–337.2	–3.9	14,927 ± 75	18,036–18,483	12758
346.8–347.8	–3.1	14,828 ± 57	17,873–18,447	12759
350.0–351.0	–3.0	15,076 ± 58	18,173–18,618	12760
357.4–358.4	–3.1	15,085 ± 60	18,180–18,629	12761
357.4–358.4	–4.2	15,151 ± 57	18,519–18,680	12762

https://doi.org/10.1017/S0033822200046518 Published online by Cambridge University Press

Table 1 δ^{13}C values, conventional ^{14}C ages, and calibrated ages for core PY608W-PC. *(Continued)*

Core depth (cm)	δ^{13}C$_{organic}$ (‰, PDB)	Conventional ^{14}C age (BP, ±1 σ)	Calibrated age (cal BP, 1 σ)	Lab code (NUTA2-)
362.7–363.7		15,207 ± 90	18,540–18,727	13245
368.0–369.0		15,289 ± 72	18,620–18,748	12138
TOC fraction				
90		12,975 ± 56	15,166–15,456	12101
190		15,655 ± 68	18,849–18,955	12147
290		14,368 ± 63	17,015–17,457	12153

[a]These samples were collected by wet-sieving (opening, 125 m) and picked out by pipette from the sediments.

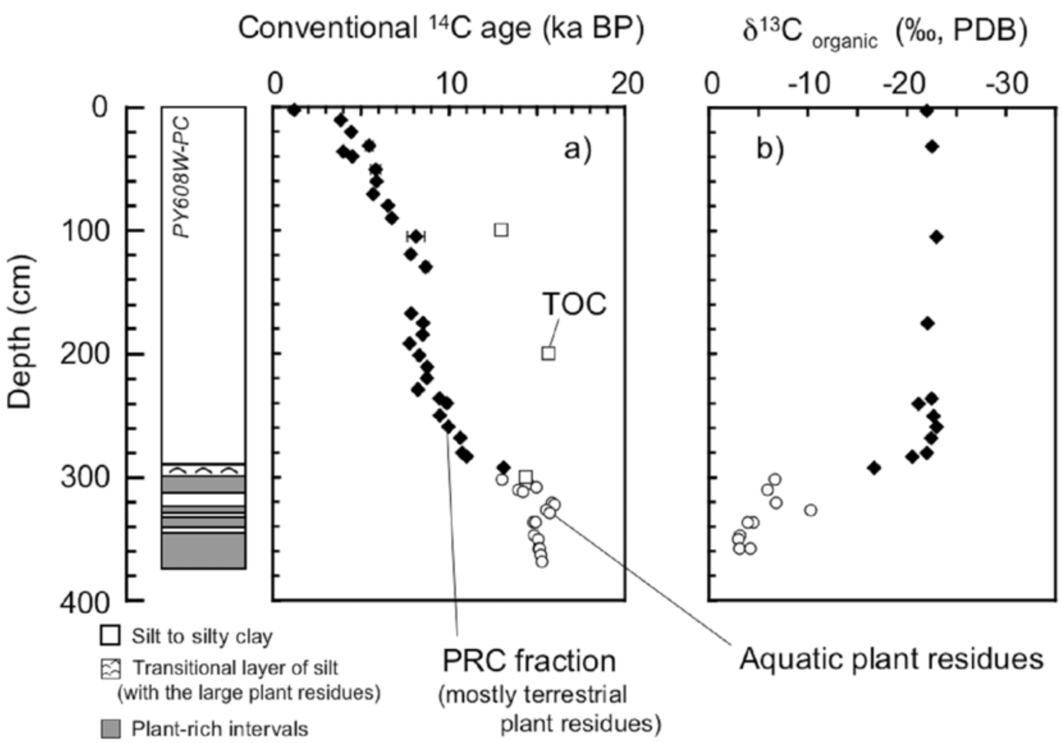

Figure 3 Downcore profiles of a) conventional ^{14}C ages of the plant residue concentrate (PRC fraction, >125 μm, mainly terrestrial plants), aquatic plant residues and total organic carbon (TOC) and b) δ^{13}C values of PRC fraction and aquatic plant residues in the PY608W-PC sediment core from Lake Pumoyum Co. The lithologic composition of PY608W-PC is also shown to the right of the ^{14}C and δ^{13}C profiles. The results for the PRC fraction and aquatic plant residues from the PY608W-PC are shown with filled diamonds and open circles, respectively. The conventional ^{14}C ages of TOC in PY608W-PC are shown with open squares.

Lake Pumoyum Co sediment core were likely composed mainly of terrestrial plant fragments from the area surrounding the lake. ^{14}C ages of the total organic carbon (TOC) fraction from PY608W-PC were older by up to ~8000 yr than those of PRC fraction (Table 1, Figure 3a). This result might have been caused by a relatively large supply of terrestrial organic materials containing old carbon ("old carbon effect"; carbon derived from lake terrace, loess, or other strata with dead ^{14}C). The old carbon effect on ^{14}C dating has been widely observed in sediments from freshwater lakes (Abbott and Stafford 1996; Moreton et al. 2004; Watanabe et al. 2007, 2009a,b).

https://doi.org/10.1017/S0033822200046518 Published online by Cambridge University Press

Age Models for Core PY608W-PC Based on Calibrated Ages of Plant Residues

In the lower layers of core PY608W-PC (380–300 cm depth), calibrated ages of the aquatic plant residues were ~19–15 cal ka BP, corresponding to the last glacial period (Figure 4). ^{14}C ages of aquatic plants are generally influenced by the reservoir effect resulting from large inflows of melting glacier and groundwater, as well as by the dissolution of carbonate rock such as limestone in the surrounding area (Hall and Henderson 1991; Hendy and Hall 2006; Jiang et al. 2006; Morrill et al. 2006). The ^{14}C content of living aquatic plants (Potamogetonaceae and Characeae) in Lake Pumoyum Co (~1–17 m water depth, 108.1–110.6 pMC, Watanabe et al. 2008; Nakamura et al. 2009) agreed well with those of tropospheric CO_2 (~108 pMC, after Morrill et al. 2006), suggesting that in modern Lake Pumoyum Co, the ^{14}C reservoir effect is negligible. Therefore, we propose that the most likely ^{14}C reservoir age of the aquatic plant residues in these layers is nearly 0 yr. However, ^{14}C reservoir ages may vary according to changes in lake environmental and climatic conditions. The age reversal under 300 cm core depth of PY608W-PC (Figure 4) might be due to changes in the ^{14}C reservoir effect in the lake and/or plant residue sources in the sediment core.

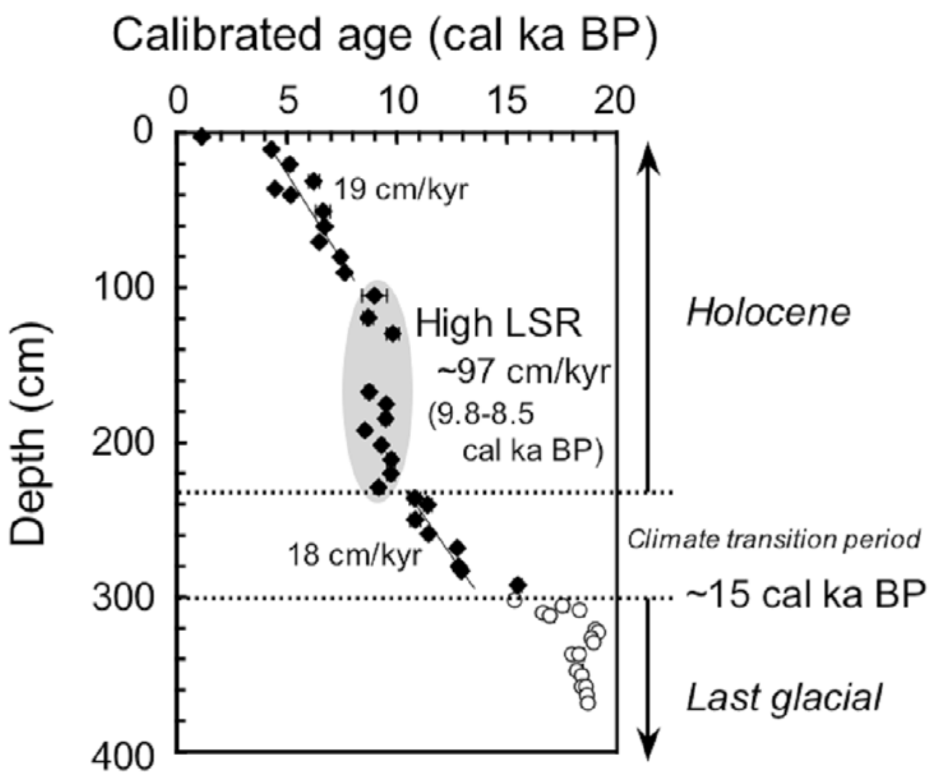

Figure 4 Calibrated ages of the plant residue concentrate (PRC fraction) and aquatic plant residues in core PY608W-PC. The ages for the PRC fraction and aquatic plant residues are shown with filled diamonds and open circles, respectively. Bold solid lines are the regression lines for the calibrated ages of the PRC fraction. The shaded area indicates layers with high linear sedimentation rates (232–102 cm core depth, 9.8–8.5 cal ka BP).

The PRC fractions in the layers above 300 cm depth in PY608W-PC dated to after the climate transition from the last glacial to Holocene (after ~15 cal ka BP). The macrophyte residues disappeared, and deposition of silty clay and silt took place during ~15 cal ka BP (transition period from the last glacial to Bølling-Allerød warm phase). This obvious lithologic change could be due to the rapid lake-level rise during the last deglaciation in the southeastern Tibetan Plateau.

In core PY608W-PC, the average linear sedimentation rate (LSR) between 15–10 cal ka BP (Figure 4), estimated using the calibrated ages of the PRC fractions, was 18 cm/kyr. The extremely high LSR value was observed for the early Holocene (between 10–9 cal ka BP, ~97 cm/kyr, 232–102 cm core depth). This high value might be due to climate amelioration and a large influx of clastic materials from the watershed as a result of the melting of mountain glaciers and increased precipitation. A previous study reported an abrupt increase in southwestern monsoon intensity between 10.3 and 9.6 cal ka BP, as determined from $\delta^{18}O$ values in a stalagmite from southern Oman (Fleitmann et al. 2003). The LSR value after 9 cal ka BP (early Holocene to present) decreased to 19 cm/kyr, a similar value to that of between 15–10 cal ka BP.

CONCLUSION

A ^{14}C chronology of the PY608W-PC sediment core (3.8 m core length) from Lake Pumoyum Co, southeastern Tibetan Plateau, was presented for the period from the Last Glacial Maximum to the Holocene (~19 cal ka BP to the present). Sediment layers of the lower part of PY608W-PC (380–300 cm depth) were composed mainly of relatively large plant residues (up to ~3 cm in length, Figure 2) with an admixture of fine sand and sandy silt. In this study, the aquatic plant residues disappeared at ~300–290 cm depth in core PY608W-PC and were replaced by silt-silty clay. The calibrated age for the lithologic boundary (about 300–290 cm core depth) was ~15 cal ka BP, which corresponds with the timing of the Bølling-Allerød warm phase.

ACKNOWLEDGMENTS

The authors thank the members of the China-Japan Scientific Research Expedition to Lake Pumoyum Co on the Tibetan Plateau, for their help during the acquisition of the sediment core samples. We are grateful to the staff of the Center for Chronological Research, Nagoya University, for the ^{14}C dating. We also acknowledge anonymous reviewers for improving manuscript. This research was partly supported by a Grant-in-Aid for JSPS Fellows to T W (No. 20-4967).

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