Preliminary Results of Pollen Analysis and Its Implications to Paleoenvironment in Paitan Lake, Nueva Ecija, Philippines

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Abstract

This paper presents the preliminary results of pollen analysis and other physical properties of cored sediments from Paitan Lake, Nueva Ecija, Luzon Island. A 300-cm core was obtained at the side of the lake using a hand auger sampler. The AMS radiocarbon date for plant fragments of 1255±25 BP indicates that the cored sediments cover the past 1200 years. Arboreal fossil pollen grains are dominant in the PL-2 pollen zone and *Melia* pollen is dominant in the PL-1 pollen zone, while non-arboreal fossil pollen grains are dominant in the PL-2 pollen zone. The fossil pollen grains of aquatic plants are also found in the PL-1 pollen zone. The paleoenvironment of Paitan Lake has changed from grass field to forest. In addition, the old lake level was much higher, as compared to the present lake level, as suggested by the presence of aquatic plants. The presence of nontronite, suggesting rapid deposition, may have been due to the existence of unaltered feldspar. The C/N ratio of the sediment suggests that organic matter was derived from predominantly land-derived plants and, probably, some plankton. Future drilling activities will target a deeper horizon to establish a tephrochronological framework in central Luzon. This will increase our understanding of the paleoenvironment and evolution of the lake.

Key words: Paitan Lake, pollen fossil, radiocarbon date, core drilling

Introduction

The Philippines is a tropical country having hot and humid weather throughout the year. This type of environment makes the plant residues decomposed at higher rate, however, phytoliths and pollens do not decompose under such conditions and are permanently stored in sediments. The analysis of vegetation changes using the phytolith has been undertaken in the Philippines (Sase et al., 1993; Higashi and Suzuki, 1996; Yoshida et al., 2011), however, the analysis of vegetation change using pollen is hardly done due to the difficulty in the identification of tropical fossil pollen grains. In this preliminary work, palynological and geological investigation was conducted by obtaining shallow cored sample from Paitan Lake. The taxa of fossil pollen grains were also determined in the sediment taken from the same core sample. We plan to conduct a more extensive research in Paitan Lake next year by drilling deeper and retrieving undisturbed core samples.

Sampling Locality and Sample Description

The Central Luzon Plain is the largest plain in the Philippines where cultivation of rice is being practiced by the local people. Paitan Lake is located at Cuyapo Municiapality in Nueva Ecija Province in the northern part of Central Luzon plain, approximately 180 km north-northeast from Manila (Fig. 1). Paitan is a volcanic crater lake with a diameter of 0.8 km (east-west) and 1.2 km (north-south). The lake has no well-defined river system that drains into and out of the lake.

The endemic genera and species are very high in the Philippines. The endemic genera are more than 30%, approximately 68% of which are endemic species, and from these endemic species 84% are approximately primary forests (Takhtajan, 1986). In this way the Philippines is richly endowed with plants. Based on the study, primary forests have once flourished in the past, however rice paddies are the dominant features that can be seen at present. The primary forests were already destroyed and sparsely exist around the private homes and along the road. These trees are *Gliricidea sepium, Samaenea saman, Pterocarpus indicus* and *Leucaena leucocephala* of Fabaceae, *Tamarindus indica* of Rosaceae, *Gmelina arborea* of Labiatae and *Corypha elata* of Arecaceae (Yoshida et al., 2011).

In September 2012, the research team obtained a 300-cm core in the paddy field located at the side of the lake using a hand auger sampler. The sampling location is at the lakeside with coordinates of 15°50'22.38" N and 120°44'7.13" E, and with elevation of 74m above sea level (Fig. 1). The 300-cm core is subdivided into four layers based on color, and these are: a) Layer 1 - dark gray silt (0 - 30 cm); b) Layer 2 - light brown clay (30 - 115 cm); c) Layer 3 - dark gray clay (115 - 228 cm); and d) Layer 4-dark brown clay (228 - 300 cm) (Fig. 2 and 3). Seven samples were taken for pollen analysis at the following depths labeled as: A - 77 cm, B - 110 cm, C - 150 cm, D - 190 cm, E - 220 cm, F - 240 cm and G - 278 cm. A sample for radiocarbon dating was taken from depth 278 cm (Fig. 3).

Analytical Methods

1. AMS radiocarbon dating

The plant fragment collected from the core at depth of 278 cm (Sample G) was purified by a routine AAA treatment, and oxidized by heating together with CuO. The produced gas was purified cryogenically to CO_2 gas using vacuum line, and then reduced catalytically to graphite on Fe powder with H_2 gas (Kitagawa et al., 1993). Radiocarbon measurement with NIST oxalic acid standard (HOxII) was conducted using the AMS system (model 4130-AMS, HVEE) at Nagoya University using method of Nakamura et al. (2004).

2. Pollen analysis

Fossil pollen and spores were extracted using 10% KOH treatment, HF treatment, $ZnCl_2$ solution treatment (Fujiki and Yasuda, 2004) and Erdtman's acetolysis method (Erdtman, 1934). Extracted pollens were dehydrated by passing through a series of alcohol (60%, 80%, and 99.5% solutions) and cleared with xylene. Residues were then mounted in Eukitt (O. Kindler) to create a permanent preparation (Fujiki et al., 2002) for observation under the light microscope. Light microscope observations were made using the Nikon XF-21 microscope and photographed at 400 times magnification. More than 500 pollen grains were identified in each sample, of which more than 200 were arboreal pollen grains. The results are expressed in percentages of each taxon, with the percentages calculated with respect to the sum of the arboreal pollen (AP).

3. Carbon and nitrogen analysis and X-ray diffraction

Seven samples (Samples A to G) were determined for carbon and nitrogen contents, and for clay minerals. Elemental analysis was conducted by using a Yanaco MT-700 according to the previously reported procedure (Goshima et al., 2005). Hippuric acid (C=60.33 %, N=7.82 %) was used as standard.
Divided samples were stirred with distilled water and allowed to settle for 3.5 hours, after which the top 5 cm of sediments with water were extracted. After separation, purified clay fraction was smeared on glass slides. X-ray powder diffraction data were obtained on a Rigaku RINT 2000 diffract meter using CuKα radiation.

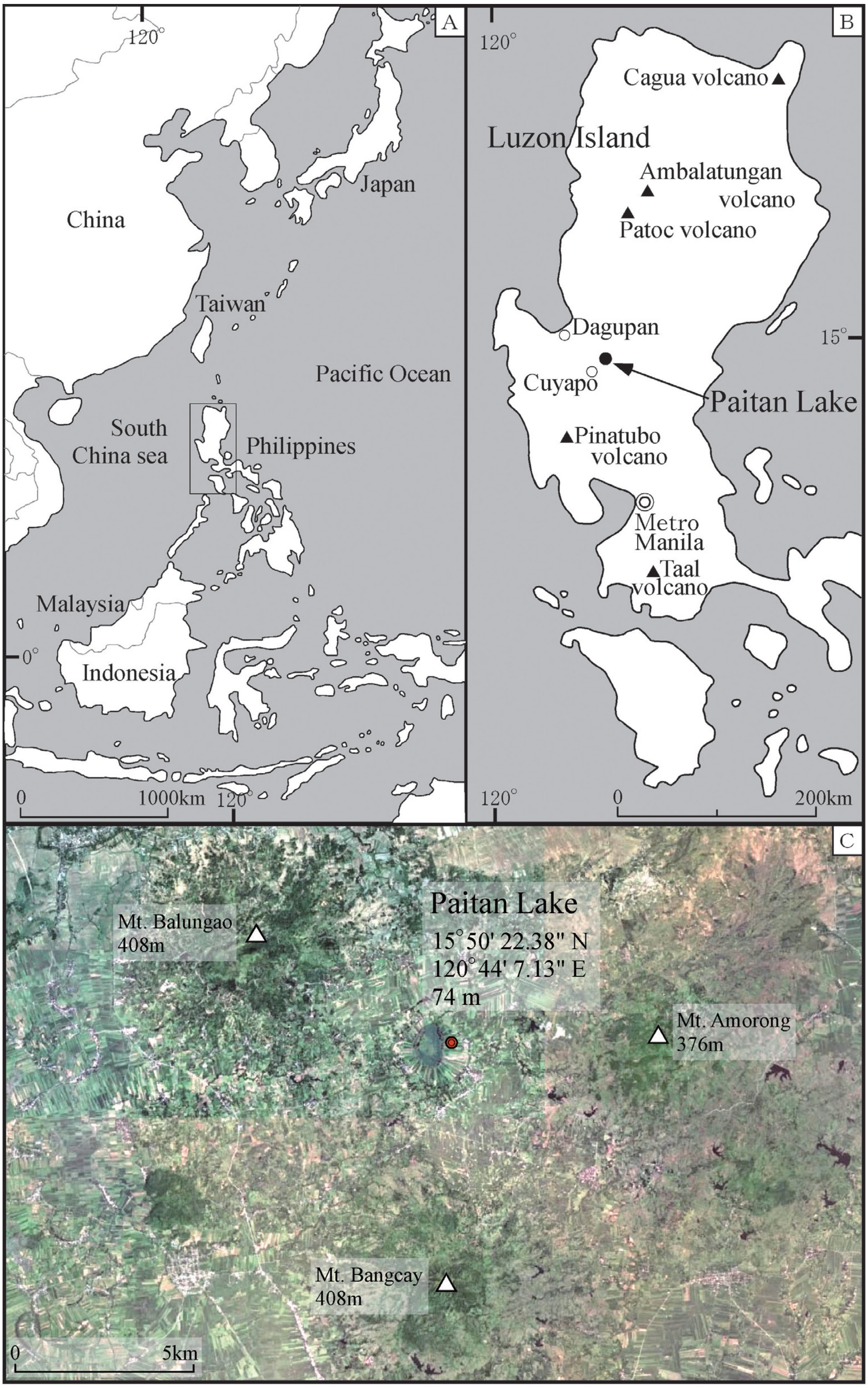

Fig. 1 Index maps. (A) Index map of the Philippines. Rectangle indicates approximate area of central part of Luzon Island. (B) Location of Paitan Lake (filled circle). Filled triangles show active volcanoes. Open circles denote city and town. (C) Satellite image around Paitan Lake (after Google map).

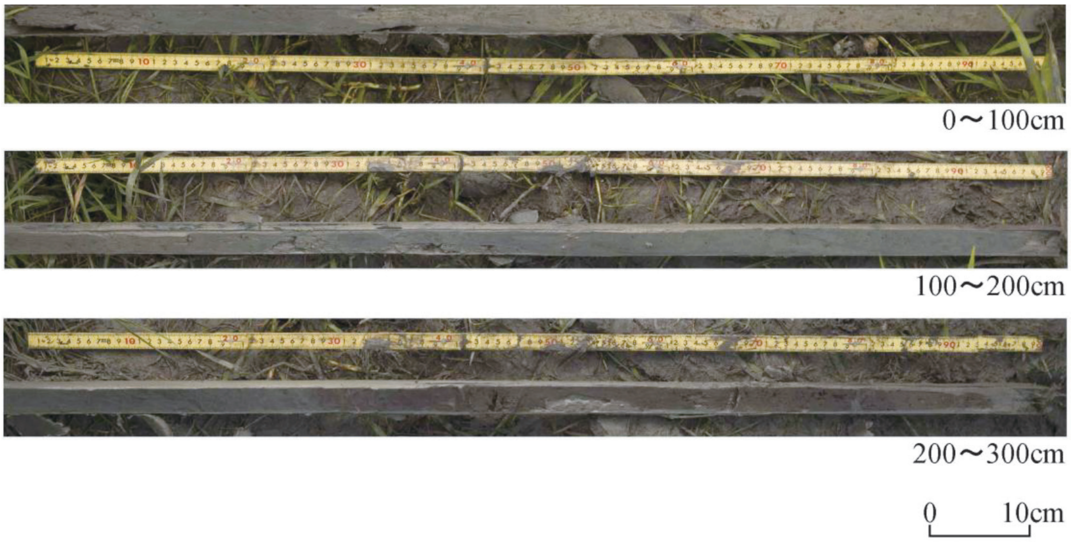

Fig. 2 The photographs of sediment from Paitan Lake.

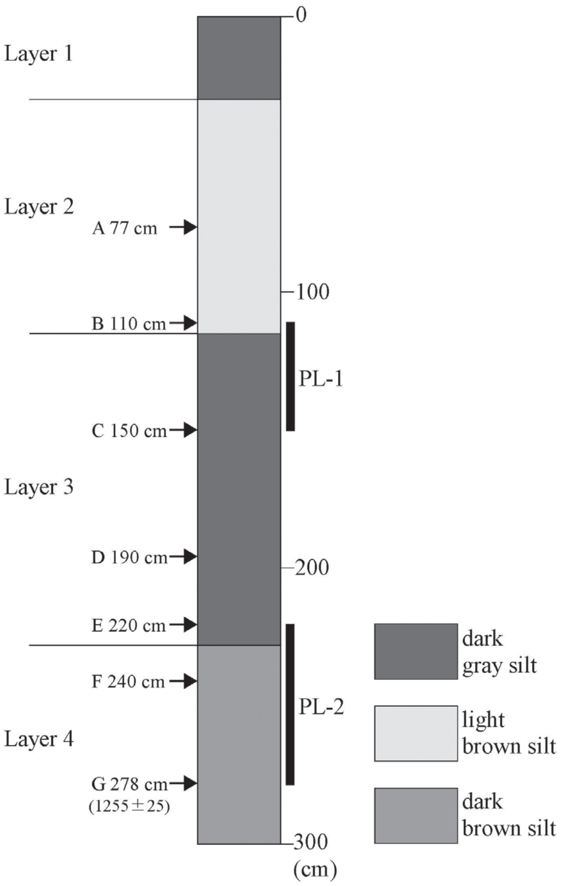

Fig. 3 Columnar section showing the stratigraphy of the core from Paitan Lake.
Arrows indicate sampling horizons.

Laboratory results

1. Depositional age

The result of AMS ^{14}C dating is shown in Table 1. The ^{14}C date is calibrated to calendar years range using IntCal09 data set (Reimer et al., 2009) with a computer program Calib 6.0 (Stuiver and Reimer, 1993; Stuiver et al., 2010). The obtained age indicates approximately 1200 cal BP at 278 cm in depth.

2. Pollen assemblages

Twenty-five varieties of fossil pollen grains and spores were identified (Fig. 4) and these were divided into AP (arboreal pollen), NAP (non-arboreal pollen) and FS (fern spore), as listed below:

AP: *Pinus, Podocarpus, Dacrydium, Casuarina, Trema, Albizia,* Rosaceae *Melia,* Malvaceae, *Bombax, Terminalia, Barringtonia, Mussaenda,* other Rubiaceae, *Weigela,* Arecaceae.

NAP: Poaceae, Cyperaceae, Cucurbitaceae, Onagraceae, Compositae, *Utricularia, Nymphoides.*

FS: monolete type, trilete type.

The analyzed data are plotted in Figs. 5 and 6. The fossil pollen content of Samples A and C is very low, and these samples are omitted from the diagram.

The fossil pollen grains of *Pinus, Melia* and *Barringtonia* dominate under 200 cm in depth. In addition, the appearance ratios of the herbaceous

Table 1. Result of AMS ^{14}C dating from Paitan Lake.

Depth (cm)	Sample	Material	$\delta^{13}C$ (‰)	^{14}C age (BP)	Calibraed years range (cal BP; probability % in 2σ)	Labo. no.
278	G	Plant fragment	-30.3	1255 ± 25	1167-1276 (88.9%) 1128-1162 (8.2%) 1090-1109 (2.9%)	NUTA2 19293

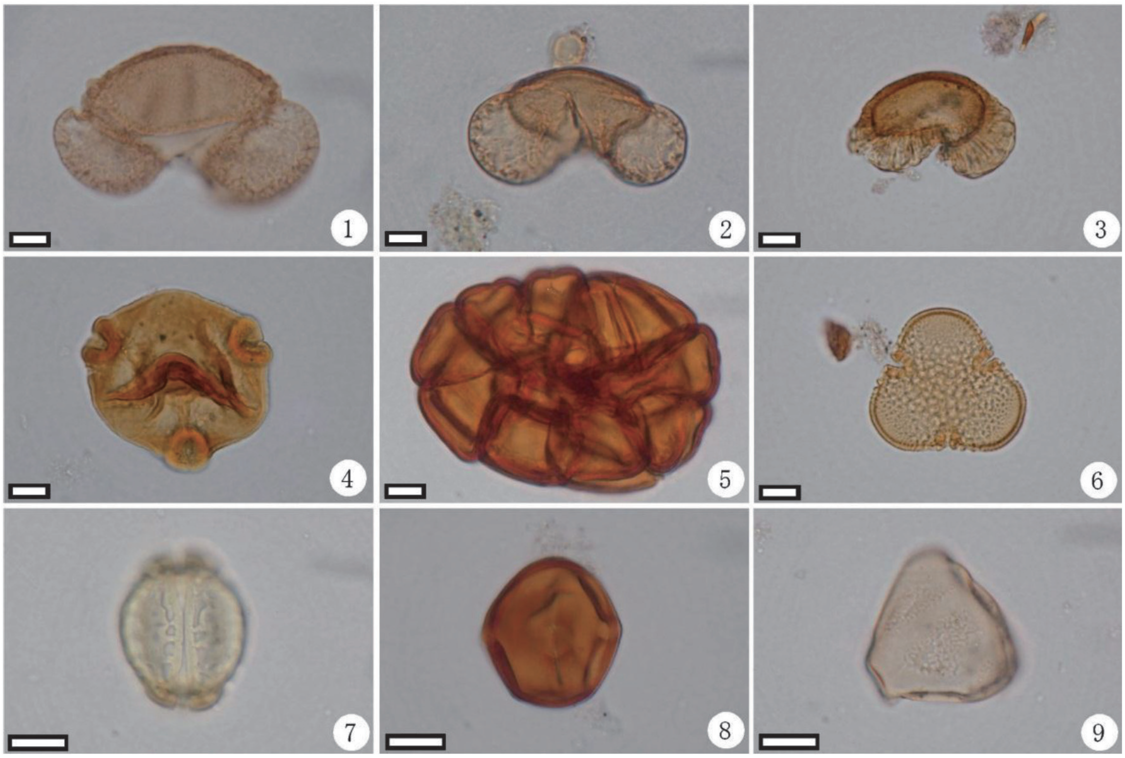

Fig. 4 Light micrographs of fossil pollen from Paitan Lake. Scale bar is 10 μm.
1: *Pinus*, 2: *Podocarpus*, 3: *Dacrydium*, 4: Onagraceae, 5: *Samanea*, 6: *Bombax*, 7: *Barringtonia*, 8: *Melia*, 9: Cyperaceae.

fossil pollen grains, such as Poaceae and Cyperaceae, are high. The fossil pollen grains of the aquatic plants, such as *Nymphoides* and *Utricularia*, appear. However, the herbaceous fossil pollen grains decrease rapidly, and the arboreal fossil pollen grains (except for *Melia*) also decrease in 150 cm. *Melia* fossil pollen is dominant in the upper 150 cm, and the percentage of this fossil pollen shows over 80%.

3. Carbon and nitrogen contents and clay mineral composition

Results of elemental analysis of seven samples are given in Table 2. Carbon and nitrogen contents were successfully measured only in two samples taken at depths of 220 cm (Sample E) and 278 cm (Sample G), respectively. The other samples were under detection limit.

XRD analysis indicates that all samples contain nontronite which is intermediate between montmorillonite and beidellite (Fig. 7). In spite of hydrological elutriation, feldspars probably plagioclase with a minor amount of orthoclase are detected from Samples A and B. Crystallinity of nontronite varies from 1.75° FWHM (full width at half maximum) (Samples A and E) to 1.95° FWHM (Sample F). No stratigraphic change of crystallinity was observed.

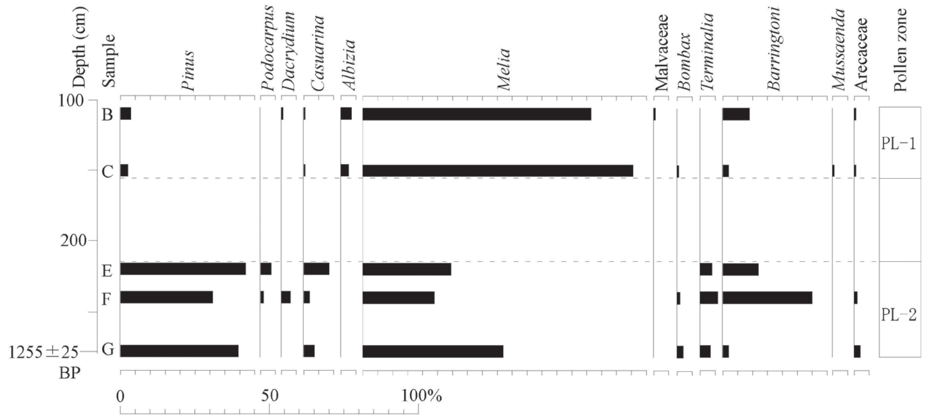

Fig. 5 Arboreal pollen diagram of Paitan Lake core.

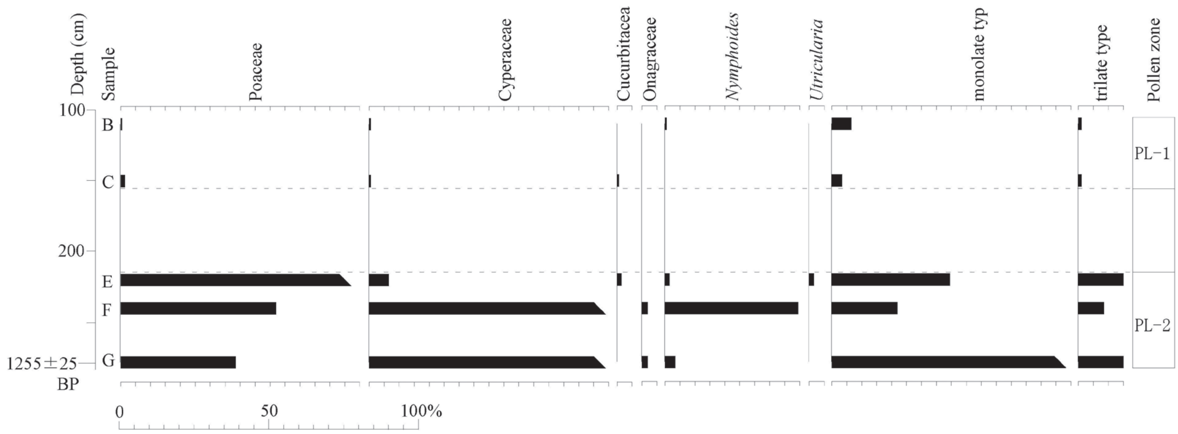

Fig. 6 Non-arboreal pollen diagram of Paitan Lake core.

Discussion

There are two pollen zones that can be identified based on dominant taxa, i.e., PL-1 pollen zone is dominated by arboreal pollen (Sample B and C) and PL-2 pollen zone is dominated by non-arboreal pollen (Sample E-G) (Figs. 5 and 6).

Arboreal pollen grains appear in all of the layers but they are dominant in the PL-1 pollen zone, indicating that forest existed throughout the sampling depth within the age 1255±25 BP (limit of our sampling depth) and probably beyond. At present, little forests are distributed in Central Luzon Plain, but vast land of forest covers the Luzon Central Plain in the past as the data suggest. The location of the current borehole site is above the lake level and currently a paddy field. Aquatic plants, such as *Nymphoides* and *Utricularia*, are also found under 200 cm, indicating that this was once below lake level. Tashiro et al. (2012) suggest that increasing the amount of precipitation and influent quantity into the lake after 2100 cal BP from the change of particle size, and it is considered that the water level of Paitan Lake was higher than at present. According to Yoshida et al. (2011), the phytolith of *Oryza* type does not appear around 1200 cal BP. It is assumed that reed (*Phragmites australis*) had grown thickly around the site. Yoshida et al. (2011) also indicated that herbaceous vegetation of Poaceae and that of tree species incresed from about 1240 to 1150 cal BP, which is consistent with our results.

The grass pollen grains and arboreal pollen grains (except for *Melia*) decreases rapidly in the PL-1 pollen zone, and only *Melia* remains dominant.

Table 2. Result of C/N analysis from Paitan Lake.

Depth (cm)	Sample	C%	N%	C/N
77	A	n.d.	n.d.	−
110	B	n.d.	n.d.	−
150	C	n.d.	n.d.	−
190	D	n.d.	n.d.	−
220	E	0.59	0.04	15
240	F	n.d.	n.d.	−
278	G	1.57	0.11	14

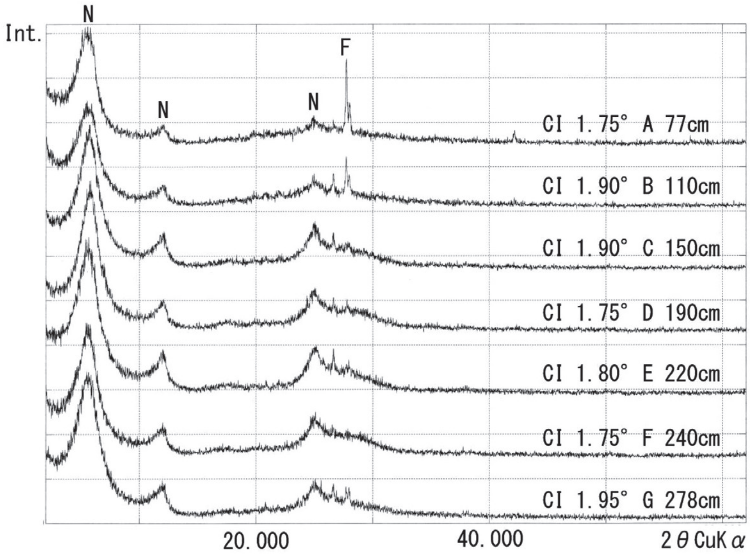

Fig. 7 The results of X-ray diffraction (XRD) patterns of from Paitan Lake core. N: nontronite, F: feldspar, CI: crystallinity index.

This indicates that the recent water level of Paitan Lake is much lower, indicating a transition from an environment submerged in water into an area covered by land. The forests, mainly composed of *Melia* tree, may have flourished.

From the carbon-nitrogen analysis, the C/N Total carbon contents of the core are: 0.59% (Sample E) and 1.57% (Sample G), while nitrogen contents are 0.04% and 0.11%, respectively. Other samples are not observed for carbon and nitrogen, indicating absence of organic matter (Table 2). It could also be reconciled with poor occurrence of pollens, especially in the upper horizon between 77 cm and 190 cm.

According to Nakai et al. (1982), terrestrial plants show high C/N values relative to marine organic matter such as plankton. In this regard, C/N values of the site are 15 for Sample E and 14 for Sample G are above normal, suggesting dominant accumulation of land plants and, probably some plankton that are rich in carbon relative to nitrogen. Though it should be considered from a wider viewpoint, both abundance and variety of plant species are governed by C/N.

Nontronite is a product of weathering or from alteration. In this case, nontronite coexists with less decomposed feldspars at depth of 77 cm suggesting rapid deposition may have occurred justifying the existence of unaltered feldspar.

Acknowledgment

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（要　旨）

藤木利之・鮎沢　潤・井村美智子・鳥井真之・中村俊夫・Danikko John Rivera・Ericson Bariso・Arturo Daag・小林哲夫・奥野　充，2013, フィリピン共和国，ヌエバ・エシハ州のパイタン湖における花粉分析の予察的結果とその古環境への意義．福岡大学理学集報，43, 73-81.（Fujiki, T., Aizawa, J., Imura, M., Torii, M., Nakamura, T., Rivera, D.J., Bariso, E., Daag, A., Kobayashi, T. and Okuno, M., 2013, Preliminary Results of Pollen Analysis and Its Implications to Paleoenvironment in Paitan Lake, Nueva Ecija, Philippines. *Fukuoka University Science Report*, **43**, 73-81.）

フィリピン共和国，ヌエバ・エシハ州のパイタン湖の湖畔において，深さ 300 cm のコア試料を掘削した．本稿では，その花粉分析と物理的特性の予察的結果を報告した．PL-2 花粉帯では樹木花粉と非樹木花粉が優占し，PL-1 花粉帯ではセンダン属の化石花粉が優占する．さらに PL-1 では水生植物の化石花粉が出現する．現在のパイタン湖周辺は，水田や草原であるが，PL-1 に相当する時期にはセンダン属を主体とする森林に覆われていた．さらに水生植物の出現が示すように，かつての湖水面は現在より高かったと考えられる．ノントロナイトの存在は，急速な堆積を示唆し，未変質な長石の存在とも調和的である．試料の C/N 比は，有機物が陸上植物を主とし少量のプランクトンに由来することを示唆する．今後，テフロクロノロジーの年代枠を確立するため，より深いコア掘削を行う予定で，包括的な古環境復元とパイタン湖の進化も確立できるであろう．