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Non-destructive analysis and lithological descriptions of sediment cores from Lake Nurume, Langhovde in Lützow-Holm Bay

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Abstract: Antarctica's lake sediments are valuable geological archives for paleoenvironmental reconstructions of sea level and ice sheet change. It is essential to proceed with an analysis of cores from several locations in one lake to reconstruct detailed environmental changes. In the geomorphological survey of the 61st Japanese Antarctic Research Expedition, we collected four sediment cores in Lake Nurume, located at Langhovde in Lützow-Holm Bay, East Antarctica. We present preliminary results of non-destructive analysis of these cores, such as X-ray CT scanning, physical properties, and visual core descriptions. The obtained results combined with geomorphological settings and model simulations, will provide insight into the potential of these cores for paleoenvironmental reconstructions in Antarctica.

1. Background & Summary

The Antarctic Ice Sheet (AIS) plays an important role in the Earth's climate system, as its decay and growth influence ocean and atmospheric circulations. Further understanding the mechanism of AIS response to climate changes is essential to understand various timescales of AIS changes. Paleoenvironmental reconstructions using geological evidence and model simulations provide more extended timescale changes than decadal measurements of the AIS in the instrumental period (e.g., Ishiwa *et al.*, 2021a[1]; Kawamata *et al.*, 2020[2]; Suganuma *et al.*, 2014[3]), which are mainly measured by geodetic and gravimetric observations (e.g., Aoyama *et al.*, 2016[4]; Fukuda *et al.*, 2021[5]; Hattori *et al.*, 2021[6]).

Lake sediments in Antarctica are useful archives for studying sea level, ice sheet, and paleoclimate (e.g., Takano *et al.*, 2012[7]; Verleyen *et al.*, 2005[8], 2017[9]; Zwarts *et al.*, 1998[10]). In this paper, we provide information on non-destructive analysis and lithological descriptions of four lake sediment cores from Lützow-Holm Bay, East Antarctica, and discuss how future analyses of these sediments will contribute to paleoenvironmental research in Antarctica.

2. Location

Lake Nurume is located at Langhovde in Lützow-Holm Bay, East Antarctica (Figure 1; Ishiwa *et al.*, 2021b[11]). The lake is 16 m deep, and the water column is stratified with an upper layer of saline and a lower layer of hypersaline water (Sano *et al.*, 1977[12]; Kurosawa *et al.*, 2010[13]; Kudoh and Tanabe, 2014[14]). It was formed by the late Holocene isostatic uplift, which isolated the basin from the sea. The sill height is ~1 m sill, and a perennial snow patch is in the southeast of the lake.

The sediment coring was conducted in the geomorphological survey of the 61st Japanese Antarctic Research Expedition (Ishiwa *et al.*, 2020[15]; 2021b[11]) using a portable coring system (Suganuma *et al.*, 2019)[16] upon the water using a boat. The four cores were collected at various depths (Figure 1d; Table 1): one is from the deepest depth of the lake, the other is from the southeastern depression, and the last two are from ~6 and 8 m depths. After taking samples in the field, samples were refrigerated and shipped to National Institute of Polar Research by *Shirase* and transported to the Center for Advanced Marine Core Research (CMCR) in Japan.

3. Methods

First, X-ray scanning using CT was conducted on the whole core in CMCR. The cores were split into working and archive halves (Figure 2). After splitting, we conducted non-destructive analysis and subsampling. The non-destructive analyses included photography and physical property measurements (magnetic susceptibility and density) using a multi-sensor core logger (MSCL). After these non-destructive analyses, the visual core descriptions of working halves were made, and sediments of working halves were cut every 1 cm into four parts: two are for refrigeration, and the others are for freezing. The samples for soft X-ray scanning were also taken for archive materials (Figure 2).

3.1. Color reflectance calculation

The photography of cores was taken in CMCR using continuous image photographic equipment with 600 dpi. The color reflectance values of photography were calculated using OpenCV in Python. We extracted RGB values from the photography and calculated L*, a*, and b* values from RGB variations (Figure 3).

3.2. CT scanning and CT value calculation

CT-scanning system is Aquilion PRIME Focus Edition designed by CANON MEDICAL SYSTEMS CORPORATION. The slice interval is 0.5 mm, and the resolution is approximately 0.16 mm. CT images were outputted from the raw DICOM data using ImageJ Fiji software (Schindelin *et al.*, 2012)[17]. The CT values were extracted from the average value of ~1.6 cm (equivalent to 100 pixels) radius from the center using Pydicom (Figure 4).

3.3. Multi-Sensor Core Logger analysis

The MSCL in CMCR is designed by Geotek Ltd. and measures density by gamma-ray and magnetic susceptibility with 1 cm resolutions (e.g., Ishiwa *et al.*, 2016[18]; Oiwane *et al.*, 2014[19]). MSCL measurements were conducted on working or archive-half sediment cores.

3.4. Visual core description

After splitting whole cores, we conducted visual core descriptions immediately. The sediment cores from Lake Nurume contain silt and fine and medium sand. The laminated layer is present in the part of all cores. However, some of these layers are difficult to observe by the naked eye and easy to find in CT scanning.

4. Data Records

The data in this paper contains three files, JARE61_LakeNurumeSectionSummary.pdf, JARE61_LakeNurumeMSCL.xlsx, JARE61_LakeNurumeColor.xlsx, and JARE61_LakeNurumeCT-values.xlsx. These files are stored in the Arctic Data archive System (ADS). The raw DICOM data of CT scanning and codes can be provided if you request the corresponding author.

5. Technical Validation

The whole cores were refrigerated before core splitting. Before MSCL measurements, the cores were left at room temperature because the calculation of magnetic susceptibility needs the temperature value of room temperature.

RGB values are extracted from the core images, and then L*a*b* values are obtained by OpenCV. Before deriving color information, the color tone of core images was corrected based on the color palette using the tone curve of Adobe Photoshop. The gray color palette was referenced, and the RGB values of gray were modified so that the red, green, and blue values were the same. Though this correction was made, part of the core images failed to produce a continuous color tone. In this case, a* value shifts, although there appears to be no change when the core images are viewed with the naked eye (Figure 3).

CT values of one line may contain pebbles in the matrix, and this CT value is not representative of its depth. While the overall average of CT values should be taken, whole cores include sediments and core liners. Moreover, we conducted percussion piston coring above the lake water level in the field, which caused the dragging of sediments against the core liner (Figure 4). For these reasons, CT values were applied to sediments around the center of the core.

Sediment depth control is essential to conducting paleoenvironmental reconstruction. The core length preliminarily relies on visual core descriptions and photography. The length of CT and MSCL measurements correspond to core liners. However, some top parts of the core liner contain no sediments. Therefore, the CT and MSCL data lengths were matched to the lengths indicated by visual core descriptions and photography by checking the measurement datasheets and measurement results.

Further analysis of the cores improves our understanding of how lake environments change in response to sea level changes. As these cores were collected above and below the chemocline, the stratigraphic structure observed in Lake Nurume will better understand when it was formed and how it changed. Moreover, the results of these analyses will progress the understanding of biological communities' change in response to these environmental changes.

6. Usage Notes

Before using the data for publication or presentation in any media, please request permission.
Inquiries should be addressed to:

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7. Figures

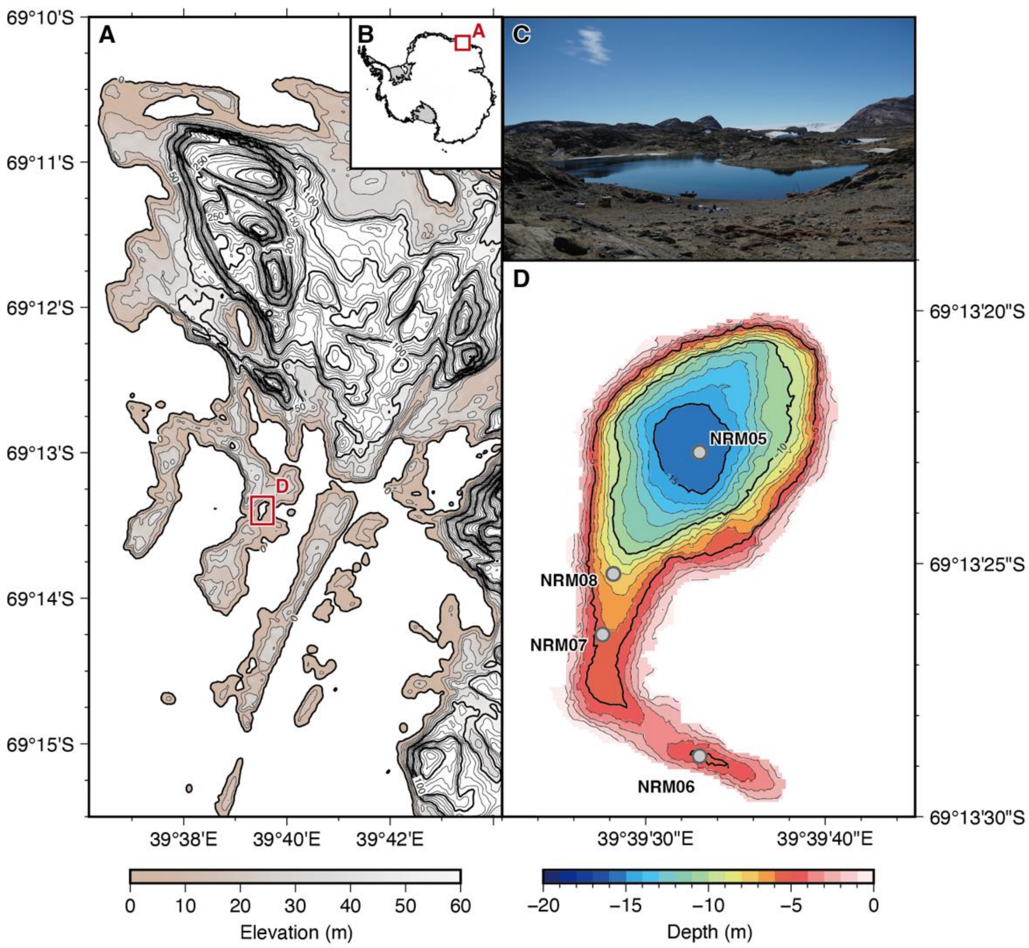

Figure 1. Maps and photographs of the study area. (A) Map of the northern part of Langhovde. (B) Map of Antarctica. (C) View of Lake Nurume (Ishiwa *et al.*, 2021b)[11]. (D) Bathymetry of Lake Nurume with coring sites. The topographic data of Langhovde is from the REMA dataset (Howat *et al.*, 2019)[20]. The bathymetry data of Lake Nurume from Ishiwa *et al.* (2021b)[11].

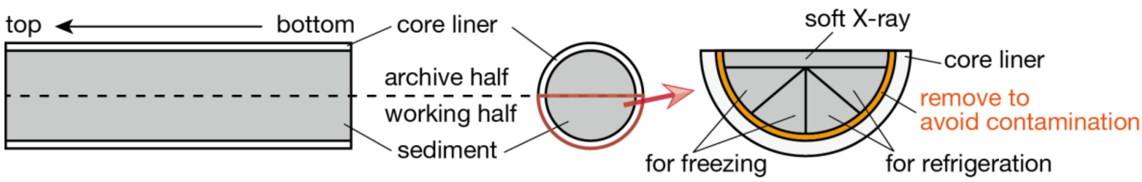

Figure 2. The sampling strategy for sediment cores from Lake Nurume.

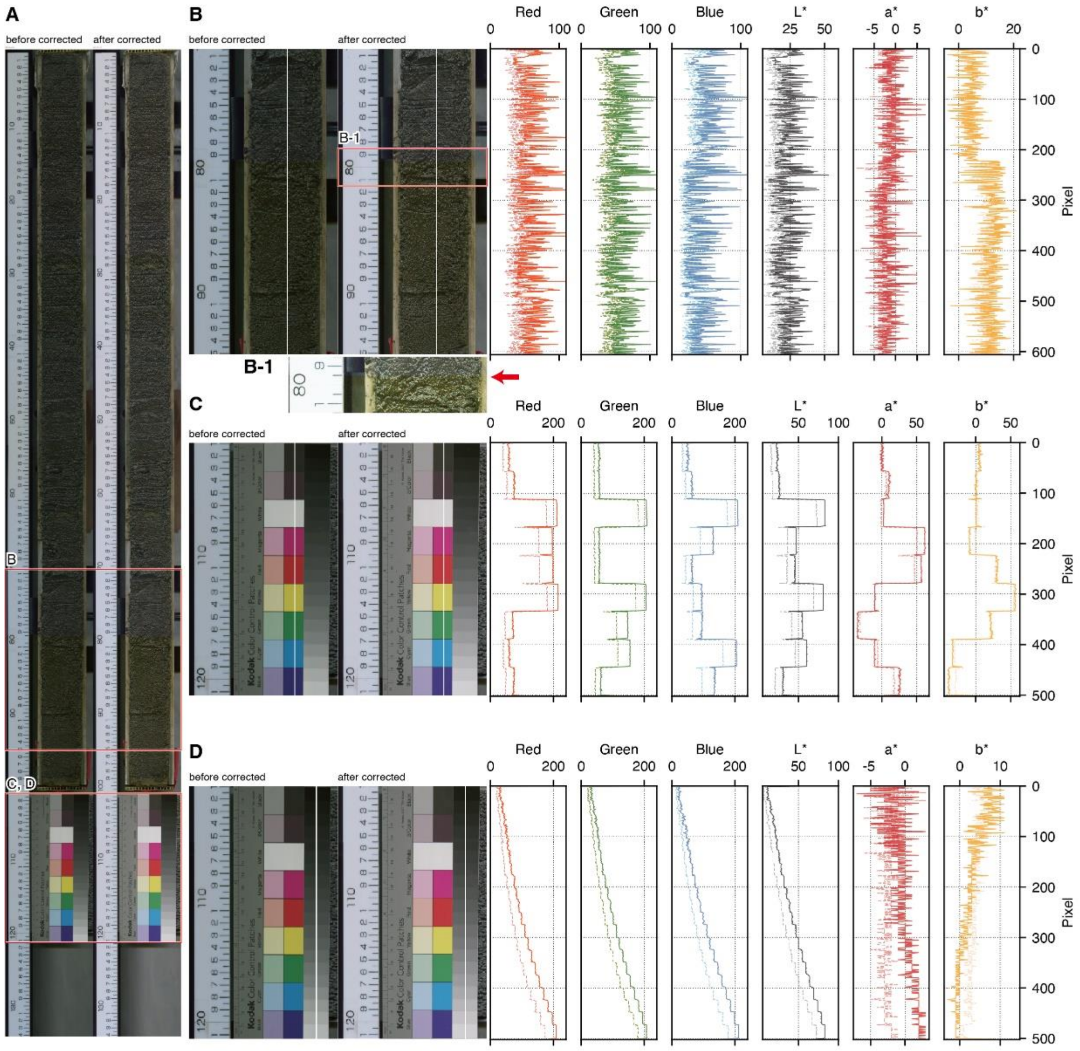

Figure 3. Core scanning and results of extracting color information of NRM05 Section 2. (A) The entire core images. The left is the uncorrected image, and the right is the corrected image by Adobe Photoshop. Panels B to D are the same deployment. (B-D) Portions of core images, RGB, and L*a*b* variations. Dashed lines are values from the uncorrected image, and solid lines are values from the corrected image. Panel B-1 is an image in which the brightness is raised to make it easier to see the boundary (a red arrow) between different color tones.

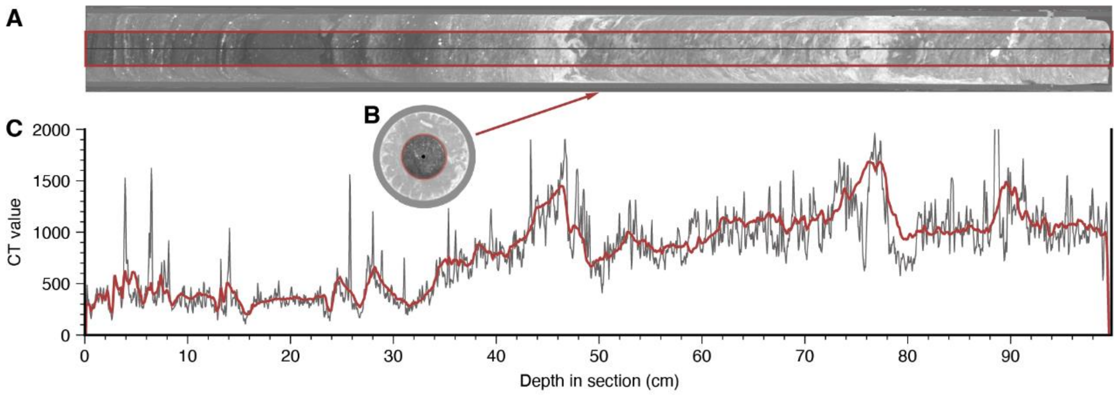

Figure 4. CT scanning image and CT values of NRM08 Section 2 using Pydicom. (A) and (B) CT image of NRM08 Section 2. The black line is the centerline of the CT values. The red shape is the area of average CT values. (C) The variation of CT values. The black line is the value of the centerline. The red line is the average CT value of the red shape in (A) and (B).

8. Tables

Table 1. Core information.

Core	Number of sections	Longitude (E)	Latitude (S)	Depth (m)	Total core length (cm)
JARE61_NRM05	3	39°39.55′	69°13.38′	15.83	266.3
JARE61_NRM06	1	39°39.55′	69°13.48′	5.1	66.5
JARE61_NRM07	2	39°39.46′	69°13.44′	6.05	212.2
JARE61_NRM08	2	39°39.47′	69°13.42′	8.1	168

Table 2. Section information.

Core	Section	Length (cm)
JARE61_NRM05	1	66.7
	2	100
	3	99.6
JARE61_NRM06	1	66.5
JARE61_NRM07	1	116.1
	2	96.1
JARE61_NRM08	1	68
	2	100

Author contributions

Sediment core samples were taken by JARE61 geomorphological survey members (TI, YT, SS, and TI). All analyses in KCC were carried out by TI, YT, SS, YS, KK, and MI. All co-authors approved this manuscript.

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References

1. Ishiwa, T., Okuno, J., and Suganuma, Y. Excess ice loads in the Indian Ocean sector of East Antarctica during the last glacial period. Geology. 2021a, 49, p. 1182–1186. https://doi.org/10.1130/g48830.1.
2. Kawamata, M. *et al*. Abrupt Holocene ice-sheet thinning along the southern Soya Coast, Lützow-Holm Bay, East Antarctica, revealed by glacial geomorphology and surface exposure dating. Quat. Sci. Rev. 2020, 247, 106540. https://doi.org/10.1016/j.quascirev.2020.106540.
3. Suganuma, Y., Miura, H., Zondervan, A., and Okuno, J. East Antarctic deglaciation and the link to global cooling during the Quaternary: evidence from glacial geomorphology and ^{10}Be surface

exposure dating of the Sør Rondane Mountains, Dronning Maud Land. Quat. Sci. Rev. 2014, 97, p. 102–120. https://doi.org/10.1016/j.quascirev.2014.05.007.

4. Aoyama, Y., Doi, K., Ikeda, H., Hayakawa, H., and Shibuya, K. Five years' gravity observation with the superconducting gravimeter OSG#058 at Syowa Station, East Antarctica: gravitational effects of accumulated snow mass. Geophys. J. Int. 2016, 205, p. 1290–1304. https://doi.org/10.1093/gji/ggw078.
5. Fukuda, Y., Okuno, J., Doi, K., and Lee, C. -K. Gravity observations at Jang Bogo Station, Antarctica, and scale factor calibrations of different relative gravimeters. Polar Sci. 2021, 29, 100702. https://doi.org/10.1016/j.polar.2021.100702.
6. Hattori, A., Aoyama, Y., Okuno, J., and Doi, K. GNSS Observations of GIA ‐ Induced Crustal Deformation in Lützow ‐ Holm Bay, East Antarctica. Geophys. Res. Lett. 2021, 48 (13), e2021GL093479. https://doi.org/10.1029/2021gl093479.
7. Takano, Y. *et al.* Holocene lake development and glacial-isostatic uplift at Lake Skallen and Lake Oyako, Lützow Holm Bay, East Antarctica: Based on biogeochemical facies and molecular signatures. Appl. Geochem. 2012, 27 (12), p. 2546–2559. https://doi.org/10.1016/j.apgeochem.2012.08.009.
8. Verleyen, E., Hodgson, D. A., Milne, G. A., Sabbe, K., and Vyverman, W. Relative sea-level history from the Lambert Glacier region, East Antarctica, and its relation to deglaciation and Holocene glacier readvance. Quat. Res. 2005, 63, p. 45–52. https://doi.org/10.1016/j.yqres.2004.09.005.
9. Verleyen, E. *et al.* Ice sheet retreat and glacio-isostatic adjustment in Lützow-Holm Bay, East Antarctica. Quat. Sci. Rev. 2017, 169, p. 85–98. https://doi.org/10.1016/j.quascirev.2017.06.003.
10. Zwartz, D., Bird, M., Stone, J., and Lambeck, K. Holocene sea-level change and ice-sheet history in the Vestfold Hills, East Antarctica. Earth Planet. Sci. Lett. 1998, 155, p. 131–145. https://doi.org/10.1016/S0012-821X(97)00204-5.
11. Ishiwa, T. *et al*. Bathymetry data and water column profiles in the shallow waters of Langhovde in Lützow-Holm Bay, East Antarctica. Polar Sci. 2021b, 28, 100650. https://doi.org/10.1016/j.polar.2021.100650.
12. Sano, M., Nakai, N., and Torii, T. On the Two-Layer Structure in Lake Nurume, Antarctica. Nankyoku Shiryo. 1977, 58, p. 63–68 (in Japanese with English abstract). https://doi.org/10.15094/00007904.
13. Kurosawa, N., Sato, S., Kawarabayasi, Y., Imura, S., and Naganuma, T. Archaeal and bacterial community structures in the anoxic sediment of Antarctic meromictic lake Nurume-Ike. Polar Sci. 2010, 4 (2), p. 421–429. https://doi.org/10.1016/j.polar.2010.04.002.
14. Kudoh, S., and Tanabe, Y. Limnology and ecology of lakes along the Sôya Coast, East Antarctica. Advances in Polar Science. 2014, 25 (2), p.75–91. https://doi.org/10.13679/j.advps.2014.1.00075.
15. Ishiwa, T., Tokuda, Y., Itaki, T., and Sasaki, S. Report on the geomorphological survey in the Soya Coast (JARE-61). Nankyoku Shiryo. 2020, 64, p. 330–350 (in Japanese with English abstract). https://doi.org/10.15094/00016229.
16. Suganuma, Y. *et al*. Development of a portable percussion piston corer. Journal of the Geological Society of Japan. 2019, 125, p. 323–326 (in Japanese with English abstract). https://doi.org/10.5575/geosoc.2018.0065.

17. Schindelin, J. *et al.* Fiji: an open-source platform for biological-image analysis. Nature Methods. 2012, 9 (7), p. 676–682. https://doi.org/10.1038/nmeth.2019.
18. Ishiwa, T., Yokoyama, Y., Miyairi, Y., Ikehara, M., and Obrochta, S. Sedimentary environmental change induced from late Quaternary sea-level change in the Bonaparte Gulf, northwestern Australia. Geoscience Letters. 2016, 3, 33. https://doi.org/10.1186/s40562-016-0065-0.
19. Oiwane, H. *et al.* Sediment waves on the Conrad Rise, Southern Indian Ocean: Implications for the migration history of the Antarctic Circumpolar Current. Mar. Geol. 2014, 348, p. 27–36. https://doi.org/10.1016/j.margeo.2013.10.008.
20. Howat, I. M., Porter, C., Smith, B. E., Noh, M. -J., and Morin, P. The Reference Elevation Model of Antarctica. The Cryosphere. 2019, 13, p. 665–674. https://doi.org/10.5194/tc-13-665-2019.

Data Citations

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