A lacustrine palynological record from Long Lake/King George

Luiz Antonio Costa Rodrigues
Federal University of Rio de Janeiro

Cláudia Barbieri Ferreira Mendonça
cb.mendonca@gmail.com

Federal University of Rio de Janeiro

Heitor Evangelista
Rio de Janeiro State University

Sergei Verkulich
Herzen State Pedagogical University of Russia

Flavia Alves Tavares
Rio de Janeiro State University

Vania Gonçalves-Esteves
Federal University of Rio de Janeiro

Research Article

Keywords: Antarctica, climate change, pollen, sedimentology, westerly winds

Posted Date: September 25th, 2025

DOI: https://doi.org/10.21203/rs.3.rs-7520482/v1

Additional Declarations:
No competing interests reported.

Table 1 is available in the Supplementary Files section.

A lacustrine palynological record from Long Lake/King George Island/Antarctica evidence the role of westerly winds on the atmospheric dispersion during Late Holocene

Luiz Antonio Costa Rodrigues[1], Cláudia Barbieri Ferreira Mendonça[1*], Heitor Evangelista[2], Sergei Verkulich[3], Flavia Alves Tavares[2], Vania Gonçalves-Esteves[1]

[1] Laboratory of Palynology, Department of Botany, Museu Nacional, Universidade Federal do Rio de Janeiro, São Cristóvão, Rio de Janeiro, RJ, 20940-040, Brazil

[2]Laboratório de Radioecologia e Mudanças Globais – LARAMG. Rio de Janeiro State University, Rua São Francisco Xavier, 524, Maracanã, Rio de Janeiro, RJ, 20550-900, Brazil

[3]Herzen State Pedagogical University of Russia, Moyka Emb., Saint-Petersburg, 191186, Russian Federation

* Corresponding author. *E-mail address:* cb.mendonca@gmail.com

ORCID

Luiz Antonio C. Rodrigues: rodriguespalino@gmail.com; http://orcid.org/0000-0003-0025-4177

Claudia Barbieri F. Mendonça: cb.mendonca@gmail.com; http://orcid.org/0000-0003-4219-6147

Sergei Verkulich: verkulich@mail.ru

Flavia Alves Tavares: flaviaalvestavares@hotmail.com; https://orcid.org/0000-0002-3011-1815

Heitor Evangelista: evangelista.uerj@gmail.com; http://orcid.org/0000-0001-9832-1141

Vania Gonçalves-Esteves: esteves.vr@gmail.com; http://orcid.org/0000-0002-2803-6027

Abstract:

A palynological analysis of a sediment core collected from Long Lake, Fildes Peninsula/King George Island/Antarctic Peninsula, revealed regional changes in depositional processes over the Late Holocene. The results revealed a record of pollen grains, spores, arthropod fragments, and fungi at top core layers, as well as intact individuals of *Drepanocladus longifolius* in deeper sections. Overall, pollen grains accompanied sedimentary laminated structures suggesting shrinkage of the climate at the pro-glacial environment, as well as an atmospheric connection between South America and the Northern Antarctic Peninsula modulated by the westerly winds.

Keywords: Antarctica, climate change, pollen, sedimentology, westerly winds

Introduction

Geographically and climatically isolated extreme environments, such as Antarctica, are crucial for detecting particles and substances that could travel globally and reach their pristine environments. It is known that the climatic conditions of the Antarctic continent modulate the occurrence of plant species in the region and constitute one of the main drivers regulating the Earth's thermal balance. Although our knowledge about the dynamics and climatic characteristics of the Antarctic polar region has expanded in the last decade, its cryosphere has been experiencing profound modifications, which influence the occurrence of endemic plant species on the continent. According to Casado et al. (2023), that have compiled isotopic data from 78 ice core records in Antarctica, the recent (last 50 years) increase in air temperature co-variates with CO_2 anthropogenic emissions, despite the influence of natural drivers as ENSO (El Niño Southern Oscillation) and AAO (Antarctic Oscillation). Concurrently, recent observations have reported extreme melting events across the Antarctic Peninsula derived from the action of atmospheric rivers that transport moisture and warm air from the (sub)tropics to the Maritime Antarctica, suggesting an atmospheric teleconnection between these regions, Gorodetskaya et al. (2023).

Despite the evidences on the transport of heat and moisture from the Southern South America to Antarctica, the transit of microparticles between these continents has been an issue to be considered, since they may trace the long-range anthropogenic impact, the strength of surface winds, desertification amplitudes among other characteristics. Along the last decades, several tracers were used to identify the effectiveness of the atmospheric transport in the regional sector: mineral dust by using radiogenic signatures as the ratios $^{87}Sr/^{86}Sr$ versus $^{143}Nd/^{144}Nd$ (Delmonte et al., 2004), a radioactive noble gas, ^{222}Rn, emitted from bare rocks and soils containing ^{238}U (Evangelista and Pereira, 2002), aerosol black carbon (Pereira et al., 2006) and more recently bacteria (Cataldo et al., 2023).

The climate variability at high latitudes has become an emerging theme in the global scenario, arousing an increasing interest of numerous research groups (Thornton et al. 2014; Chen et al. 2014). A tool still little explored that may contribute to the better understanding of the changes in polar regions is the analysis of palynomorphs in natural samples, considering a scenario of newly formed ice-free areas, human occupation and a highly dynamic climate. The findings from these investigations can support the results from numerical modeling and better describe past atmospheric processes, taking into account the biogeography of pollen species. Previous studies, by microparticle analyses showed the existence of atmospheric connections in the South Hemisphere capable of transporting biological particles over distances greater than 3000 km (Câmara et al. 2023). In addition, palynological studies can add substantial accuracy to sediment core deposition history and associated paleoclimatology and help elucidate Holocene and contemporary climate variability.

Antarctic lacustrine environments are a valuable environmental matrix for the recovery of pollen samples. Antarctic lakes are predominantly formed by the melting of permafrost layers, winter snow and glacial streams. During deglaciation and melting seasons, these processes transport large amounts of organic and mineral particles into their water bodies resulting from ground biological activity and rock weathering (Giralt et al. 2020). In this study we investigated new pollen data from dated mid-to-late Holocene sediment core layers of Long Lake/Fildes, Peninsula/King George Island/Antarctic Peninsula, and examined the data under the light of the regional summer temperature, contemporaneous palynology in Patagonia and the reconstructed westerly winds. Combining these databases, we investigate the ability of pollen and palynomorphs to act as tracers of the westerly winds strength in the study region.

Material and methods

Study site

Fildes Peninsula is one of the first ice free areas to be set in the South Shetland Archipelago, after the Last Glacial Maximum. According to Barsh and Maüsbacher (1986) deglaciation at Fildes probably took place before 6000 years BP, in the Mid-Holocene. The last glacial expansion occurred between 1200 and 1800 AD, during the period known as the Little Ice Age, and is recorded at lateral and frontal moraines (Curl 1980). The extensive glacial lake network was due to insufficient drainage of the exposed surface together with high precipitation, and a topographic of sinkholes-gullies, Simonov et al. (1977). Different kind of lake landscape are identified in this region. Firstly, the proglacial environments, closer to the Bellingshausen Ice

Dome, that are directly influenced by ice and meltwater (Benn and Evans 2010). Also, paraglacial environments, in transition zones, marked by rapid adjustments after glacial retreat, and periglacial environments which are dominated by freeze-melt processes in areas more distant without glacier influence (Slaymaker 2009). The Southern and Central Fildes Peninsula periglacial lakes, as the Lake Long, don't receive hydrological-sedimentary input from the glacier anymore, and are fed by permafrost melting, snow and/or water precipitation (Petsch et al. 2017). At that region, the average annual precipitation ranges from 350 to 500 mm, with most snow and liquid rain occurring during the summer (Rakusa-Suszczewski et al. 1993). The winter is characterized by maritime climate (Smith et al. 1996) with succession of low-pressure centers forming the circumpolar westerly wind zone (Turner and Leonard 1996).

Sediment core sampling and dating

A lake sediment core measuring 100 cm in length and 6 cm in diameter was collected from the center of Long Lake (code: LL2-IAEA), Fildes Peninsula, King George Island (62°13′14.0″S 58°57′38.0″W) during the summer of 2015, as part of the UN/FAO/IAEA project titled "Assessing the Impact of Climate Change and its Effects on Soil and Water Resources in Polar and Mountainous Regions, INT/5/153." The sediment core was retrieved using a gravity hammer version of a UWITEC corer, consisting of a 1.2 m plastic tube installed on a fixed tripod on a floating platform (Fig. 1). Core was transported to Brazil, refrigerated in vertical position, inside the Brazilian Polar vessel Ary Rongel, H-44. In laboratory, the core was firstly submitted to two non-destructive analysis: Magnetic Susceptibility (see next item) at Universidade Federal Fluminense/Brazil and submitted to X-ray at the Department of Radiology/HUPE of Rio de Janeiro State University, using a Simiens/Fokus equipment (Evangelista et al. 2024).

Subsequently, sediment samplings of 1 cm resolution for pollen anaylis and subsamplings for ^{14}C were conduted under very clean conditions.

The Long Lake sediment core chronology was performed based on AMS ^{14}C analysis at Beta Analytic Laboratory. Dating was taken over dry bulk sediments treated with acid-alkali-acid treated following standard protocols which results are reported herein as conventional ^{14}C ages according to Stuiver and Polach (1977). Thereafter, conventional ^{14}C ages were calibrated using the SHCal20 calibration curve (Hogg et al. 2020). AMS results and chronology are presented in Table 1. Below 64 cm depth, very low carbon content did not allow ^{14}C analysis. The linear regression obtained from data at Table 1 resulted in: (Year cal BP) = 1,703 + 50.61 x Z(cm); p=0.002, r=0.99). Our result presented comparable ages with previously inferred chronologies (Yong et al. 2007; Watcham et al. 2011) for the top sediment section.

Magnetic Susceptibility

Magnetic Susceptibility (MS) is defined as the degree of magnetization of a material in response to an applied magnetic field. Changes in magnetic susceptibility correlate with changes in sedimentary provenience and/or diagenetic environment. Because of that MS has been used as primarily proxy indicator for changes in composition that can be linked to paleoclimate-controlled depositional processes. During warmer periods, erosional processes associated to meltwater increase the bulk magnetic susceptibility of detrital material apportioning the lake body. As temperature decreases and the glacier melting process ceases, sedimentation is restricted to pelagic material which is composed by silicious diatoms, aquatic plants and fragment of moss. This results in a decrease of the bulk magnetic susceptibility since the relative proportion of detrital material is diluted. For the MS analysis in this study, we used Multi Sensor Core Logger (MSCL) from Geotek.

Co-variability of climate proxies

For comparison with our pollen database, we chose 3 associated parameters: (1) The summer seasonal temperature variability reconstructed for the West Antarctica, based on a 50-yr δD averages data for the Holocene (Jones et al. 2023). This reconstruction uses the high-resolution water-isotope record (δD) from the West Antarctic Ice Sheet (WAIS) Divide ice core (WDC)18–20, obtained with a continuous-flow technique that provides millimetre-scale depth resolution; (2) Since we postulate that Southern Patagonia is, potentially, a major source-term of pollens and palynomorphs to Northern Antarctic Peninsula, we used total land pollen accumulation rate (influx), from the present to 6,700 yr B.P., obtained by a Holocene palaeoecological record from a ombrotrophic peat bog near Punta Burslem (54º54´S, 67 º57´W) on Isla Navarino, Tierra del Fuego (McCulloch et al., 2020); as proxy of westerly wind we used the paleovegetation Apiaceae undiff./Asteraceae subf. Asteroideae index (Moreno et al. 2009). This ration responds to the precipitation since it is the primary parameter controlling the floristic composition of the forest–steppe ecotone at southwest Patagonia (Lago Guanaco). It is the result solely of the westerly winds action and therefore more precipitation is related to more moisture transport and consequently to westerly wind intensity.

Atmospheric dispersion model (NOAA/HYSPLIT)

The effectiveness of the atmospheric transport between Patagonia and Northern Antarctic Peninsula was inferred here over three scenarios: (a) a typical neutral year (2013/2014) – Niño indexes (MEI or SOI) close to zero; (b) a typical strong La Niña year (2010/2011); and (c) a typical strong El Niño year (1997/1998). For these years, air masses past migrations were inferred from the NOAA/HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory) model. The HYSPLIT model is an atmospheric trajectory modelling tool widely used to model dispersion and deposition of mineral dust, sea salt and several pollutants. HYSPLIT is a platform developed by ARL (Air Resources Laboratory), belonging to NOAA (National Oceanic and Atmospheric Administration) and available online (http: //ready.arl.noaa.gov/HYSPLIT.php). The method of calculating the model is a hybrid between the Lagrange approach (using a mobile reference for advection and diffusion calculations as the trajectories move from their initial location) and the Eulerian methodology (which uses a fixed three-dimensional grid as a frame reference points for calculating pollutant concentrations in the air). In the case of the present work, forward trajectories were obtained and summarized by a Kernel smoothing, allowing a gradient of trajectory densities.

For the modelling we used an altitude of 200 m AMSL and the REANALYSIS meteorological database. The period that correspond each trajectory image output correspond to end of austral Spring and begging of Summer being representative of the Southern Patagonia flowering period (September-October-November-December). Two measurements per day, for each month, were performed, starting every 12 h local time; for a total of 120 hours (run time).

Sample preparation for palynological analysis

Samples were prepared for palynological analysis according to the method proposed by Yebert et al. (1992), which consists of acidification with 10% hydrochloric acid to eliminate carbonates, followed by treatment with 40% hydrofluoric acid to eliminate silicates and 10%

hydrochloric acid to eliminate fluorosilicates. Pollen grains and spores were recovered by the sieving method proposed by Oliveira (2004). Microscope slides were prepared and then analyzed under light and fluorescence microscopes. The terminology for size, shape, aperture number, and sexine ornamentation pattern follows Punt et al. (2007).

Results and Discussion

Long Lake exhibited laminated sedimentary structure, from X-ray radiograph, exhibiting clear light and dark density band formations. This feature reveals sequential deposition of organic clay-rich material (dark-colored) interbedded with silty to sandy material (light-colored). The formation of these laminated structures is commonly found in temperate, subpolar, and proglacial environments and represents successive cold-to-warm climatic phases. From our dating, the sequencial ligh-and-dark sedimentary bands do not represent annual, but decadal to centenal variabilities and point to vigorous long-term regular climate processes taking place at Northern Antarctic Peninsula during Late Holocene. The laminated pattern is better evidenced in the upper 50 cm depth. According to Evangelista et al. (2024) this difference occour due to marine to terrestrial transition due to terrain uplift during deglaciation at King George Island. Pollen detection was mostly concentrated at the top laminated section between 0 – 11 cm, that corresponds to approximately 1,703 yr B.P to 2,260 yr B.P. MS data presented 2 peaks, one between 1,500 and 2,500 yr B.P. and a second 5,500 yr B.P to 6,500 yr B.P. A minimum was observed between 4,000 yr B.P and to 5,500 yr B.P.

Analysis of palynomorph concentration revealed a heterogeneous distribution in the above section. Pollen analysis revealed the presence of the following palynomorphs in the sediment fraction: plant fragment, Pteridaceae, Hydrodictyaceae, hyphal fragment, Poaceae, Malvaceae, *Assulina muscorum* (Greeff 1888) (Euglyphidae), unidentified microalgae, trilete spore, Cyperaceae sp., Lentibulariaceae sp., *Scleria verrucosa* Willd. (Cyperaceae), Betulaceae sp., and arthropod fragment. The identified vascular plant species are predominantly shrubby or arboreal.

The palynological description recovered from the sediment core presented following characteristics: (a) Arthropod fragment (65.0 µm) (Fig. 2A); (b) Plant fragment (55.0 µm) (Fig. 2B); (c) Pteridaceae, unidentified species, heteropolar monolete spore, medium-sized (45.0 µm), surface baculate (Fig. 2C); (d) *Monactinus simplex* (Meyen) Corda (Hydrodictyaceae), adult form, radiosymmetric, medium-sized (65.0 µm), surface spinose (Fig. 2D); (e) Hyphal fragment, good integrity, color altered by the chemical treatment during sample processing (60.0 µm) (Fig. 2E); (f) Poaceae, unidentified species, pollen grain shed in monad, medium-sized (45.0 µm), aperture not observed, exine psilate (Fig. 23F); (g) Malvaceae, unidentified species, pollen grain shed in monad, medium-sized (45.0 µm), aperture not observed, exine spinose (Fig. 2G, H); (h) Euglyphidae, *A. muscorum*, fragmented specimen, medium-sized (45.0 µm), surface psilate (Fig. 2I); (i) Unidentified microalga, spinose (37.5 µm), scabrate (Fig. 2J); (j) Indeterminate spore, trilete spore fragment, heteropolar, medium-sized (44.5 µm), surface scabrate (Fig. 2K); and (k) Poaceae.

In Figure 3 we summarize the parameters at Northern Antarctic Peninsula and Southern Patagonia. Pollen data refers to top 11 cm, that corresponds to approximately 1,703 yr B.P to 2,260 yr B.P. We divided the role database in four sedimentological intervals: (i) the top core section where pollen was found and sediment core laminated structures are better recognized. In this period, MS data reaches a peak coinciding with westerlies reconstruction for Patagonia (as suggested by McCulloch et al. 2020). This elevated values of MS indicate possible increase in the erosive processes around the lake while stronger westerlies and higher pollen flux are indicative of more efficient southward transport of heat and bioaerosols. This sedimentological section is also characterized by higher summer air temperatures (inferred from δD) for West Antarctica (Jones et al. 2023). A comparison of pollen occurrence, MS and reconstructed summer air temperatures for this Late Holocene period suggests that most pollen detected in top sediment core layers of Lake Long can be the result of both direct atmospheric depositions, reaching the lake by fallout, or being transported from the surrounding soils (lake catchment) to the inside of the lake by the streams formed by melting of snow deposited during winter-spring seasons. Important to highlight raising from Figure 3 the fact that the occurrence of pollen in KGI/Northern Antarctic Peninsula was coincident to combination of parameters: pollen maxima at Southern Patagonia, recorded from approximately 4,000 yr B.P and 1,700 yr B.P. and westerly winds maxima (inferred from the ratio Apiaceae/Asteraceae) in the same period (Moreno et al. 2009), that makes us assume that Southern Patagonia is the main source-term of the detected pollen species and palynomorphs of Figure 2; (ii) in this section, despite the high summer temperatures, MS data decreased simultaneously to decrease in westerly winds. Even during high pollen flux at Patagonia, no corresponding record was observed at KGI, that highlight the relevance of the westerly winds on the transport mechanism, despite the high proximity of the two investigated sites; sections (iii) and (iv) correspond to the marine phase of the sediment core, before crustal uplift (Evangelista et al., 2024) leading to a decrease in its depositional characteristics. In section (iii) very low flux in Patagonia also corresponded to none pollen observation at KGI, during lowering of summer temperatures, that suggests none apportionment from Patagonia or other potential source-terms for pollen at KGI, as Australia or Southern Africa. In section (iv) a recovery of the intensity of summer temperatures coincided with increase in the MS signal, which shows the high correspondence of these two parameters at KGI.

While considering pollen biogeography, the predominant occurrence of shrub and tree species with current tropical distribution reinforces the hypothesis of possible exotic origin of pollen records as suggested by (Câmara et al. 2023; Rodrigues et al. 2023). Palynological data and the identification of mats of the moss *D. longifolius* (moss species widely considered a bipolar taxon) in non-overlapping sections (17–25 and 29–35 cm) with high integrity state of preservation suggests that the deposition is recent, not fossil input (before Holocene). A similar approach to the one reported by Cartapanis et al. (2022) for a 7 m sediment core collected in the same lake. The dispersion of pollen from Southern Patagonia and the Northern Antarctic Peninsula, was inferred from the dispersion model NOAA/HYSPLIT, taking into account most extreme cases related to atmospheric dynamics in the study region. During El Niño events the pressure over the Amundsen Sea is higher than normal and near-surface winds predominate from northwest to southeast, driving more moisture and warmer air into the western Antarctic Peninsula. This results in raising air temperatures and reduced sea ice. Conversely, La Niña events can strengthen the Amundsen Sea Low, potentially allow the increase of sea ice and bring lower air temperatures to Northern Antarctic Peninsula. In this study we modeled three specific cases: a typical neutral year (2013/2014), a typical strong La Niña year (2010/2011) and (c) a typical strong El Niño year (1997/1998). At all cases, the pollen dispersion between the two continents is feasible, specially in case of La Niña years.

Conclusions

This study conducted a combined geochemical-palynological investigation in Long Lake/King George Island-Antarctic Peninsula, demonstrating that palynomorphs detected in sediment layers possibly originate from the weathering of surrounding soils and mineral aggregates presented in its catchments. The morphological structure also points to an origin from the ~~and~~ atmospheric deposition driven by either dry or wet deposition and reinforce the concept in which the atmospheric connections between the South America and the Northern Antarctic Peninsula were active throughout the Late Holocene. The palynological analysis of the sediment core revealed a diverse assemblage of palynomorphs, which were interpreted in combination with absolute dating and X-ray radiometric profile of the core. The occurrence of *D. longifolius* along the sediment core is a significant finding, as it demonstrates the recent deposition of sediments in the lake. The results of this study show the potential of periglacial lakes palynological analysis as a tool to retrieve past atmospheric circulation patterns during the Holocene at the Maritime Antarctica.

Author contributions

Material preparation, data collection and analysis were performed by LACR. All authors commented on previous versions, read, and approved the final manuscript. All authors were responsible for the conception of the manuscript and contributed to its final writing.

Conflict of interest

The authors declare no conflict of interest in the present work.

Acknowledgments

V. Gonçalves-Esteves and C. B. F. Mendonça are grateful to the Brazilian National Council for Scientific and Technological Development (CNPq) for the research grants (grants nos. 304910/2019-8 and 31618/2021-9). All authors thank the Rio de Janeiro State Research

Foundation (FAPERJ) (grant Nos. 260003/015254/2021 and E-26-/203.007/2017). We extend our thanks to the Brazilian Center for Research in Physics for providing access to the scanning electron microscope and Andre Rossi and Raquel Pires, from the National Museum at the Federal University of Rio de Janeiro, Brazil, for conducting the analyses. We thank the National Institute of Science and Technology of the Cryosphere (INCT-Cryosphere/MCTIC/CNPq - 465680/2014-13), FAPERJ project E-26/201.218/2021 and CNPq project 440899/2023-0 "Rios Atmosféricos da Antártica: detecção, implicações sobre o degelo, transporte atmosférico e suas teleconexões com os (sub)trópicos" for the financial support and the Bellingshausen Russian Antarctic Station and IAEA TC project INT/5/153 for field support in Antarctica. Ao programa de Pós-Graduação em Ecologia e Evolução da Uerj (PPGEE) e ao Programa de Pós-Graduação em Geociências da Uerj (PPGG).

References

Barsch D, Mausbacher R (1986) New Data on the Relief Development of the South Shetland Islands. Antarctica-Interdisciplinary Science Review 11: 211–218

Benn DI, Evans DJA (2010) Glaciers and Glaciation, 2ed., Hodder Education, London.

Câmara PEAS, Lopes FAC, Bones FLV, Rodrigues LAC, Carvalho-Silva M, Stech M et al. (2023) Investigating aerial diversity of non-fungal eukaryotes across a 40° latitudinal transect using DNA metabarcoding. Austral Ecology 48: 1178–1194

Cartapanis O, Jonkers L, Moffa-Sanchez P et al. (2022) Complex spatio-temporal structure of the Holocene Thermal Maximum. Nat Commun 13: 5662

Casado M, Hébert R, Faranda D et al. (2023) The quandary of detecting the signature of climate change in Antarctica. Nat. Clim. Chang 13: 1082-1088

Cataldo M, Evangelista H, Pereira JAA, Bertho AL, Pellizari V, Kuhn E et al. (2023) Aerobiology in High Latitudes: Evidence of Bacteria Acting as Tracer of Warm Air Mass Advection reaching Northern Antarctic Peninsula. An. Acad. Bras. Ciênc 95 https://doi.org/10.1590/0001-3765202320210807

Chen A, Zhao C, Zhang H et al. (2024) Albedo de superfície regula o efeito climático direto do aerossol. Nat Commun 15: 7816

Curl JE (1980) A glacial history of the South Shetland Islands, Antarctica. Ohio State University. Institute of Polar Studies Report 63: 129

Evangelista H, Pereira EB (2002) Radon Flux at King George Island, Antarctic Peninsula. J Environ Radioact 61: 283-304

Evangelista H, Verkulich S, Mavlyudov B, Echer MPS, Licinio MV, Dercon G et al. (2024) Lacustrine sedimentation patterns at the Northern Antarctic Peninsula and surroundings as a response to late Holocene and Modern Climate changes. Sci Rep 14:32084

Giralt S, Hernández A, Pla-Rabes S, Antoniades D, Toro M, Granados I, Oliva M (2020) Holocene environmental changes inferred from Antarctic lake sediments. Past Antarctica, 51–66. DOI:10.1016/B978-0-12-817925-3.00003-3

Gorodetskaya IV, Durán-Alarcón C, González-Herrero S et al. (2023) Record-high Antarctic Peninsula temperatures and surface melt in February 2022: a compound event with an intense atmospheric river. npj Clim Atmos Sci 6: 202

Jones TR, Cuffey KM, Roberts WHG (2023) Seasonal temperatures in West Antarctica during the Holocene. Nature 613: 292–297

McCulloch RD, Blaikie J, Jacob B, Mansilla CA, Morello F, De Pol-Holz R, San Román M, Tisdall E, Torres J (2020) Late glacial and Holocene climate variability, southernmost Patagonia. Quat Sci Rev 229: 106131. doi:10.1016/j.quascirev.2019.106131

Moreno PI, François JP, Villa-Martínez RP, Moy CM (2009) Millennial-scale variability in Southern Hemisphere westerly wind activity over the last 5000 years in SW Patagonia. Quat Sci Rev 28: 25–38

Oliveira AD, Mendonça Filho JG, Carvalho MA, Menezes TR, Lana CC, Brenner WW (2025) Novo método de preparação palinológica para aumentar a recuperação de dinoflagelados. Rev. Bras. Paleontol 7: 169-175

Pereira EB, Evangelista H, Pereira KCD, Cavalcanti IFA, Setzer AW (2006) Apportionment of black carbon in the South Shetland Islands, Antarctic Peninsula. J. Geophys. Res. 111, D03303, doi:10.1029/2005JD006086

Petsch C, Rosa KK, Simões CL, Simões JC (2017) Morfologia de feições geomorfológicas periglaciais e proglaciais da Península Fildes. XVII Simpósio Brasileiro de Geografia Física Aplicada, Campinas/SP 6243-6252

Punt W, Blackmore S, Nilsson S, Le Thomas A (2007) Glossary of pollen and spore terminology. Rev Paleobot Palynol 143, 1-81

Rakusa-Suszczewski S, Mietus M, Piasecki J (1993) Weather and climate. In: Rakusa-Suszczewski S. The maritime Antarctic coastal ecosystem of Admiralty Bay. Polish Acad Sci, Warsaw 19-25

Rodrigues LAC, Mendonça CBF, Licínio MVVJ et al. (2023) Diversity of pollen grains transported from South America to the Antarctic Peninsula through atmospheric dispersal. Polar Biol 46: 773-782

Simonov IM (1977) Physical-geographic description of the Fildes Peninsula (South Shetland Islands). Polar Geogr. 1: 223-242

Slaymaker O (2009) Periglacial and paraglacial processes and environments. In: Knight J, Harrison SSC (eds) Special Publication. The Geological Society, Londres p.71–84

Smith RC, Stammerjohn SE, Baker K (1996) Surface air temperature variations in the western Antarctic Peninsula Region. In: Ross RM, Hofmann EE, Quetin LB (eds) Foundations for ecological research west of the Antarctic Peninsula. American Geophysical Union, Antarctic Research Book Series 70: 105–121

Stuiver M, Polach HA (1977) Relatório de Discussão de Dados de 14C. Radiocarbono 19: 355-363

Thornton PK, Ericksen PJ, Herrero M, Challinor AJ (2014) Climate variability and vulnerability to climate change: a review. Glob Chang Biol 20: 3313-3328

Turner J, Leonard S (1996) Synoptic scale weather systems around the Antarctic Peninsula from satellite imagery and model fields. In: 8th Conference on Satellite Meteorology and Oceanography 28: 574-577

Watcham EP, Bentley M.J, Hodgson DA, Roberts SJ, Fretwell P, Lloyd JM et al. (2011) Radiocarbon dates from lakes on Fildes Peninsula, King George Island. Quat. Sci. Rev. 30(21-22): 3152-3170

Ybert JP, Salgado-Labouriau M, Barth OM, Lorscheiter ML, Barros MA, Chaves et al. (1992) Sugestões para padronização da metodologia empregada em estudos palinológicos do Quaternário. Rev. Inst. Geol 13: 47-49

Yong IL, Lim HS, Yoon HI, Tatur A (2007) Characteristics of tephra in Holocene lake sediments on King George Island, West Antarctica: implications for deglaciation and paleoenvironment. Quat. Sci. Rev. 26: 25–28

Legends

Figure 1 – (a,b) Fildes Peninsula and its location at King George Island; (b) Long lake site at the ice free region of Fildes Peninsula; (c) LL2-IAEA sediment core sampling at Long Lake; (d) a view of Long Lake.

Figure 2 – Palynological record of Long Lake sediment core section (Upper 1 m): A. Fragment of arthropod, B. Fragment of vegetal, C. Pteridaceae, D. Hydrodictyaceae, E. fragmento de hifas, F. Poaceae, G-H. Malvaceae, I-J. *Assulina muscorum* (Euglyphidae), K. Pteridaceae, L. Poaceae. Scale (black bold line): 10 µm.

Figure 3 – Sedimentological-climate-palynological composite data: (A) sediment core X-ray-chronology-pollen data; (B) Magnectic Susceptibility; (C) 50-yr summer air temperature (from δD) for West Antarctica ice core (Jones et al., 2023); (D) Total pollen from Southern Patagonia from McCulloch et al. (2020); (E) and westerly winds proxy from a paleovegetation index Apiaceae/Asteraceae, Moreno et al. (2009); i, ii. Iii and iv are sedimentological sections defined to the core.

Figure 4 – Atmospheric dispersion for modern extreme scenarios, during ENSO events in three different conditions: (a) a typical neutral year (2013/2014); (b) a typical strong La Niña year (2010/2011); and (c) a typical strong El Niño year (1997/1998).

Table 1. AMS ^{14}C analysis by Beta Analytic Laboratory for Long Lake sediment core. LL2-IAEA. Sediments below 64 cm had insufficient carbon mass to provide ^{14}C data.

Figures

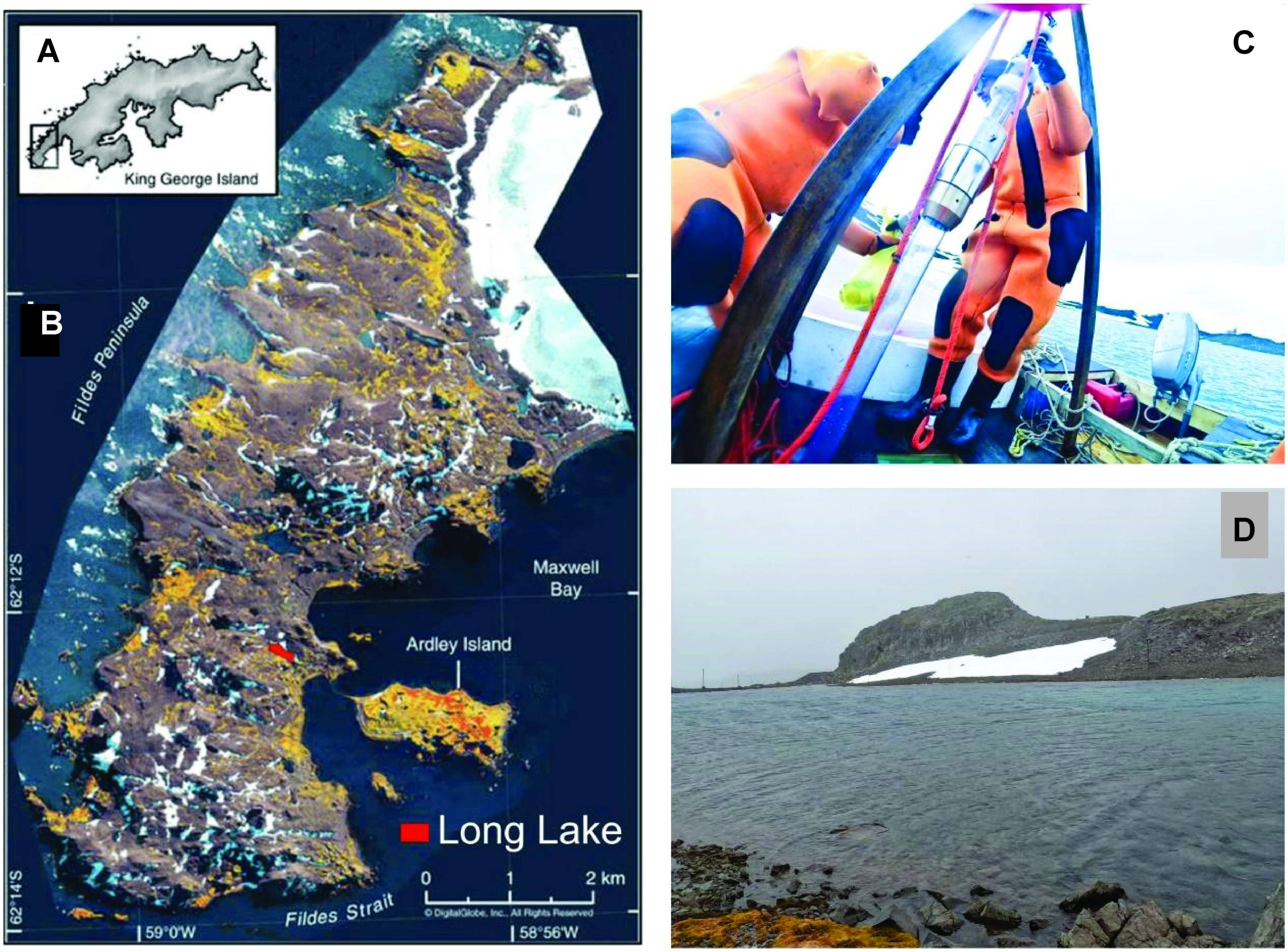

Figure 1

(a,b) Fildes Peninsula and its location at King George Island; (b) Long lake site at the ice free region of Fildes Peninsula; (c) LL2-IAEA sediment core sampling at Long Lake; (d) a view of Long Lake.

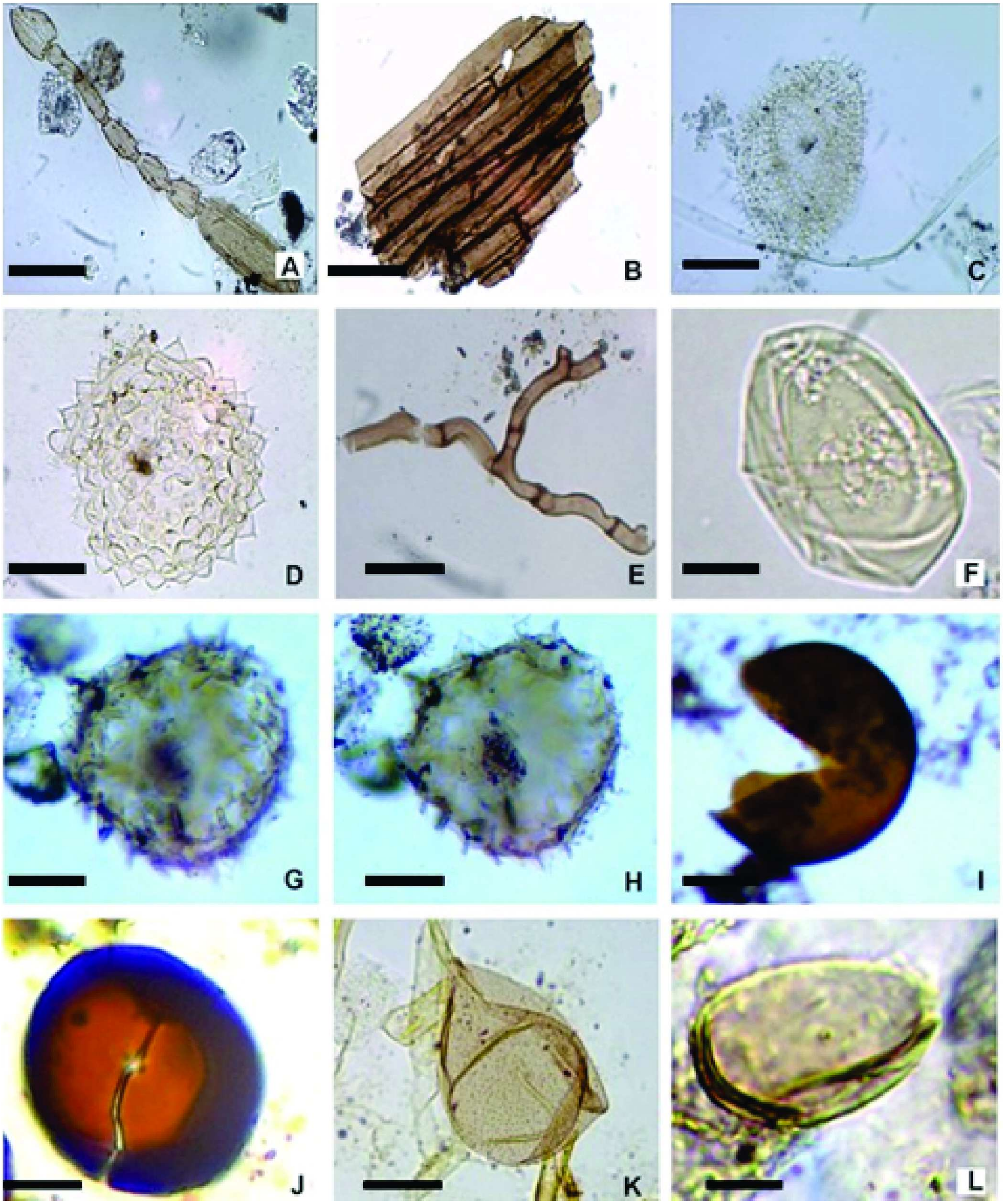

Figure 2

Palynological record of Long Lake sediment core section (Upper 1 m): A. Fragment of arthropod, B. Fragment of vegetal, C. Pteridaceae, D. Hydrodictyaceae, E. fragmento de hifas, F. Poaceae, G-H. Malvaceae, I-J. Assulina muscorum (Euglyphidae), K. Pteridaceae, L. Poaceae. Scale (black bold line): 10μm.

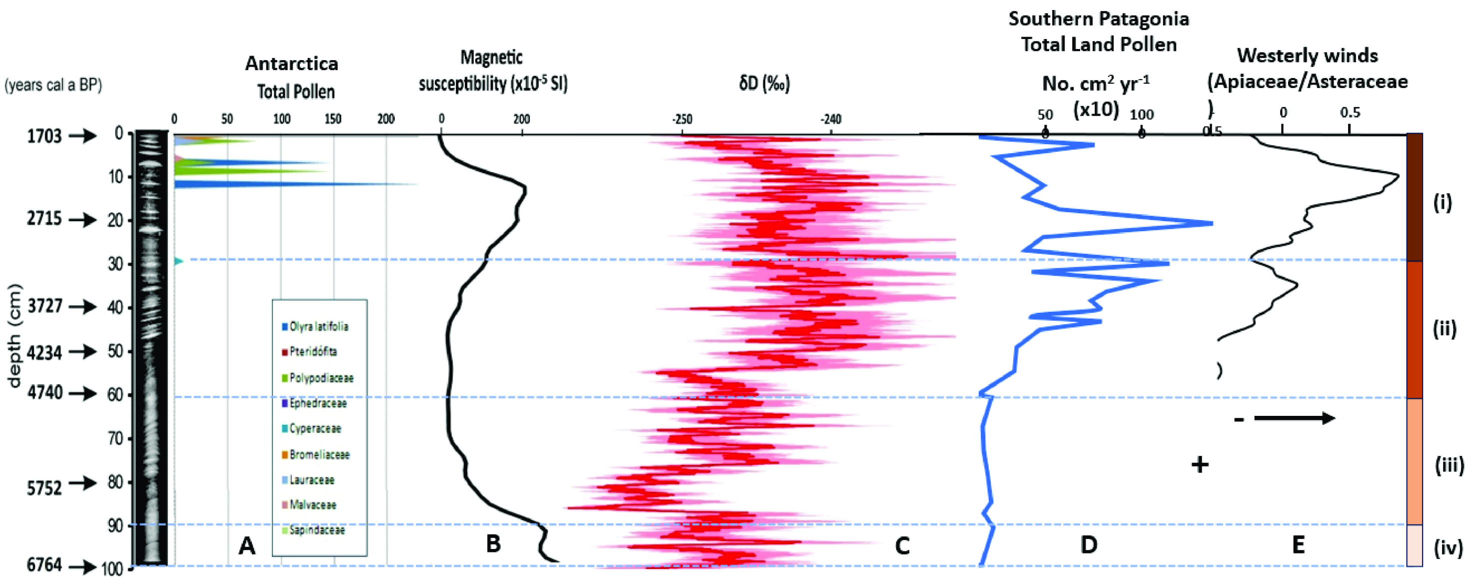

Figure 3

Sedimentological-climate-palynological composite data: (A) sediment core X-ray-chronology-pollen data; (B) Magnectic Susceptibility; (C) 50-yr summer air temperature (from δD) for West Antarctica ice core (Jones et al., 2023); (D) Total pollen from Southern Patagonia from McCulloch et al. (2020); (E) and westerly winds proxy from a paleovegetation index Apiaceae/Asteraceae, Moreno et al. (2009); i, ii. Iii and iv are sedimentological sections defined to the core.

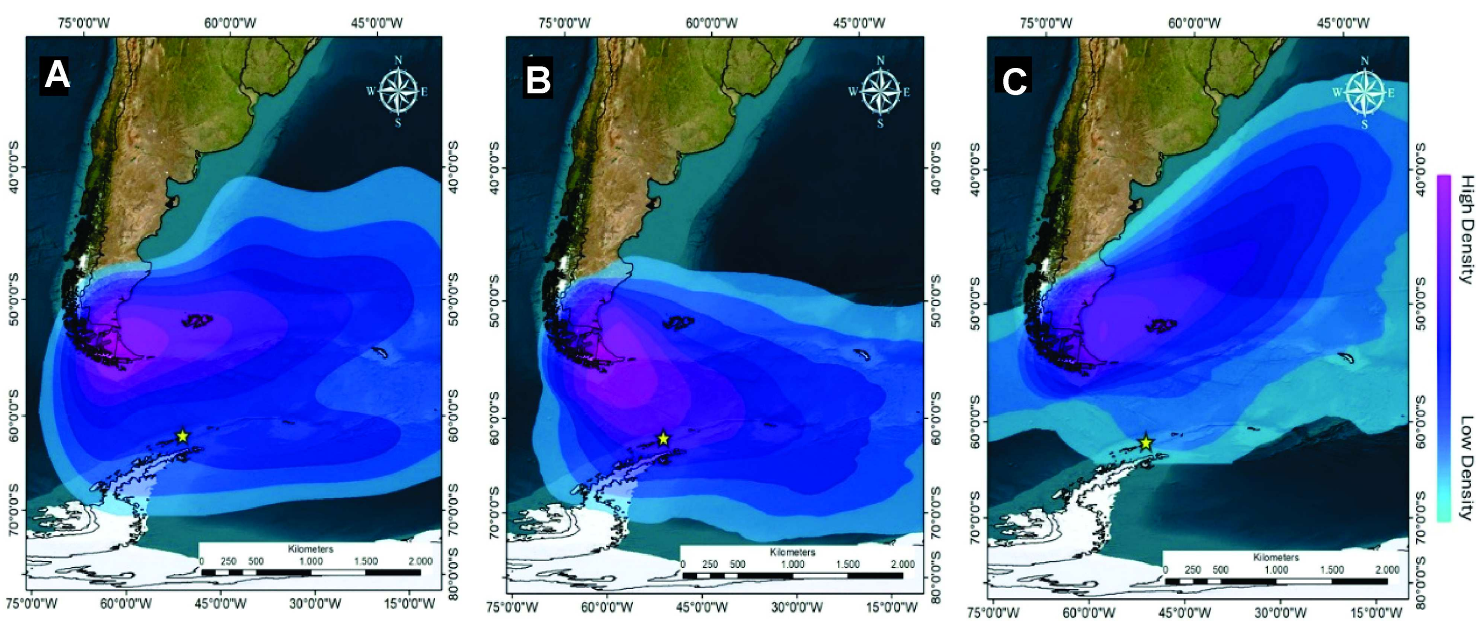

Figure 4

Atmospheric dispersion for modern extreme scenarios, during ENSO events in three different conditions: (a) a typical neutral year (2013/2014); (b) a typical strong La Niña year (2010/2011); and (c) a typical strong El Niño year (1997/1998).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Tab1.doc