frontiers | Frontiers in Ecology and Evolution

TYPE Editorial
PUBLISHED 04 January 2024
DOI 10.3389/fevo.2023.1352925

OPEN ACCESS

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RECEIVED 09 December 2023
ACCEPTED 18 December 2023
PUBLISHED 04 January 2024

CITATION
Bao K, Aránguiz-Acuña A and Cao X (2024) Editorial: Paleolimnology: insights from sedimentary archives.
Front. Ecol. Evol. 11:1352925.
doi: 10.3389/fevo.2023.1352925

Editorial: Paleolimnology: insights from sedimentary archives

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KEYWORDS

paleolimnology, lake sediments, peat, Holocene, Anthropocene, paleoecology, geochemistry, pollution

Editorial on the Research Topic
Paleolimnology: insights from sedimentary archives

In the past century, global changes characterized by warming and intense human activities have led to unprecedented changes in lake and wetland ecosystems worldwide (Smol et al., 2005). The series of ecological and environmental issues that have arisen have attracted widespread attention from governments and the scientific community in various countries. Scientifically assessing the impact of climate change and human activities on lake and wetland ecosystems has become one of the important scientific topics that are currently being prioritized (Long et al., 2021). It is also the key content of research in related disciplines such as paleolimnology, Quaternary science and past global changes (PAGES).

The study of paleolimnology interprets lake and wetland sedimentary profiles which are terrestrial archives that can record natural and human-induced changes in the environment, preserved in biological, sedimentological, and geochemical components of the sediment (Frey, 1988). The global occurrence, high accumulation rates and a wealth of microfossils and biogeochemical tracers of lake and wetland sediments allow developing the past environmental change history of sub-decadal to millennial scales. This can place the present-day observed change into the context of long-term natural environmental variability, and provides a potential means for the investigation of the interactions between past climatic dynamics and anthropogenic activities, in the absence of long-term instrumental monitoring programmes (Moser et al., 2019; Bao et al., 2023).

Over the past 40 years, the field of paleolimnology has made significant progress in contributing to our knowledge of long-term climate change (i.e., Villacis et al., 2023), altered biogeochemical cycles (i.e., Bao et al., 2021), environmental pollution (i.e., Kissinger et al., 2023), variations in dust composition and deposition (i.e., Chen et al., 2020), and species invasions and biodiversity (i.e., Cuenca-Cambronero et al., 2022). An overview of the importance of sediment records from continental aquatic ecosystems, especially lakes,

was given out to provide long-term insights needed to ensure the maintenance of ecological products and services by adapting to current and future environmental changes (Saulnier-Talbot, 2016). Recently there are series of Research Topics on paleolimnology to be published in different journals. In 2020 *Lake and Reservoir Management* presented a Research Topic on paleolimnology and lake management which includes studies from lakes across North America and shows the value of paleolimnology in making decisions regarding aquatic ecosystem restoration and management approaches (Paterson et al., 2020). In 2022 the Research Topic, entitled"Paleolimnology and Paleoecology in a Rapidly Changing Asia", was publish on *Journal of Paleolimnology* and summarized the key advances in the fields of lake development, ecological shifts and anthropogenic forcing in the different parts of East Asia (Chen et al., 2022). In 2023, Tunno et al. provided an overview of new methodologies recently applied to the field of paleoecology which was published on *Frontiers in Ecology and Evolution*. These all show a flourishing paleolimnology decipline, with continuously increasing numbers of paleolimnological investigations and updating proxy analysis technologies. However, paleolimnological studies in the tropics still lag far behind efforts at higher latitudes, and there will now be calls to encourage more paleolimnological research at low latitudes (Escobar et al., 2020).

Therefore, the objective of this Research Topic is to further address key aspects of global paleolimnological research in dealing with lakes and wetlands records of climate change and anthropogenic impacts and to facilitate knowledge dissemination. A total of 12 papers is presented in this Research Topic. The papers cover multiple themes, including chronological techniques and model applications, comprehensive interpretation of multiple alternative indicators, historical reconstructions of the past climatic, environmental and ecological evolution throughout the Holocene, and the human traces for the global Anthropocene definition. Geographically, these case studies include a variety of lakes and wetlands from 83°N to 34°S and from 170°E to 120°W. They are of mountain lakes and peatlands as higher up to 4000 m above the sea level, arctic lakes and ponds, and coastal wetlands.

Accurate and precise dating of sediments and peats is fundamental for to provide quantitative measurements of change rates, which require a relatively large number of dates to build a chronology of sufficient resolution for proxy interpretation and paleolimnological records comparison between sites. In this Research Topic, all studies used the radiocarbon dating to understand the Holocene environmental changes and the ^{210}Pb and ^{137}Cs dating to reconstruct the history of Anthropocene environmental changes. It is quite crucial to ensure a certain abundance of different sources of carbon that can be extracted from sediments for radiocarbon dating analysis. A pilot study was conducted at two contrasting lake basins on the eastern side of the Sierra Nevada (California) to present an improved method for extracting, sorting and dating pollen from lake sediment cores (Tunno et al.). This new technique combines an optimized pollen extraction protocol (without using strong chemicals, e.g., hydrofluoric acid), sorting by flow cytometry, and standard graphitization and AMS radiocarbon measurement methods. This is a very valuable contribution to the chronological methodology for the paleolimnology.

The basic paradigm of combining the past and the modern in the paleolimnology study is to use the past pattern to discuss the modern situation and to use the modern process to prove the past change. With the development of the paleolimnology, there is an increasingly urgent to the integration of modern environment/ecology into paleoenvironment/paleoecology (Goodenough and Webb, 2022). Modern processes mainly include the regional environmental factors survey and typical lakes and wetlands ecological monitoring. In this Research Topic, 3 papers explored surface-sediment taxa-environment relationships and their spatial changes of pollen in East Siberia (Geng et al.), diatom along the ice-free margin of Greenland (Weckström et al.) and zooplankton Bosminidae in the middle and lower reaches of the Yangtze River (Cheng et al.). These modern spatio-environmental studies of different proxies are an essential part of the paleolimnological approach, which is helpful for the quantitative reconstruction of the past environmental changes.

The Holocene is a typical interglacial period and generally characterized by a relatively warm and stable climate, but it is constantly interrupted by a series of rapid (or extreme) climate change events, threatening the development of human civilization. As a result, the Holocene climate and environmental changes history has always been keynotes of the paleolimnology and well comparatively documented by comprehensive interpretation of multiple alternative indicators. The sedimentary environment and hydroclimate evolution since the last glacial maximum were reconstructed from a mountain peat core of the southern margin of the Sichuan Basin based on concentrations in major and trace elements, total organic carbon (TOC), total nitrogen (TN) and the stable carbon isotope composition of organics (δ^{13}Corg) (Huang et al.). Another high-altitude lacustrine record in the semiarid Andes (29°S) was reconstructed from a multiproxy approach including organic/inorganic matter content and trace elements along with biological proxies such as pollen, diatoms and chironomids, which illustrated the climate-driven changes at millennial to sub-centennial timescales during the past 2400 years in the semiarid Andes of central Chile (Martel-Cea et al.). In addition, two paleolimnological studies from estuarine environments in China (Ling et al.) and in South Africa (Kirsten et al.) interpreted the observed changes in the geomorphic settings in the context of sea-level rise and anthropogenic factors since the mid-Holocene. Both studies obtained a series of sediment cores representing contrasting estuarine habitats and applied for multiple proxy analyses including a range of physicochemical characteristics (organic matter content, magnetic susceptibility, particle size, organic δ^{13}C and selected elements) and paleoecological parameters (pollen, Dinoflagellate, and Foraminiferal organic linings).

To understand fully current trajectories of the Earth system driven by the Great Acceleration since the mid-20th century

(Steffen et al., 2018), we need to increasing studies trying to provide more evidence for better understanding of the global definition of the Anthropocene and the decipher of human-climate interaction. Recent developments in multi-proxy paleolimnological approaches and short-time-scale chronological methods (i.e., ^{210}Pb and ^{137}Cs) have substantially advanced our ability to make robust inferences about past century's environment change. In this Research Topic, a representative subalpine lake (Cuoqia Lake) in the southeast of Tibetan Plateau was chosen as a monitor of regional environmental and ecological changes over the past two centuries based on ^{210}Pb and ^{137}Cs dates and multiproxy data including brGDGTs, n-alkane, and fatty acids (Yan et al.) and geochemistry, stable isotopes and sedimentary pigments (Zhang et al.). Statistical analyses and scenario ecosystem process-based modelling quantified the synergistic impacts of climate warming and anthropogenic activities on the algal proliferation and community succession in remote alpine lakes on the Tibetan Plateau (Zhang et al.). Multi-proxies records (black carbon, 16 priorities of PAHs and δ^{13}C) from a ^{210}Pb dated peat profile in Altay Mountain of northwest China indicated an increase of black carbon emission in 1950–1980 probably due to the agricultural exploration and a decrease after 1980 probably related to the increasing environmental protection (Luo et al.). In addition, Jaque et al. used different proxies (magnetic properties, geochemical analysis, loss on ignition, satellite image processing, and reflectance spectrum) on a reservoir sediment record in the Aconcagua River Valley to unravel the environmental and/or climatic history in central Chile between 1975 and 2019, and thus to evaluate the effects of climate drought events and regional polluting industrial activities.

In summary, the articles collected in this Research Topic provide insight into some of the most recent advances in dating methods, contemporary ecological processes, Holocene climate change and Anthropocene environmental pollution. They underlined the importance of the application of new tools and multiply proxies, and thus a comprehensive understanding of paleoenvironmental changes and their interactions with human-climate system. Paleolimnological studies are presenting a thriving development trend and provide a broad suite of information on the occurrence of ecological conditions, climate events and anthropogenic disturbances, especially for missing long-term monitoring data in remote regions. We hope that the data, insights, and recommendations offered in the present Research Topic will be of use to our readers and to paleolimnological communities at large.

Author contributions

KB: Funding acquisition, Writing – original draft, Writing – review & editing. AA-A: Writing – review & editing. XC: Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. KB acknowledges support from the National Natural Science Foundation of China (Grant Number 41971113) and the Scientific Research Foundation for Young Talents of South China Normal University (118/8S0593).

Acknowledgments

The authors are grateful to Scott Andrew Mensing (University of Nevada, United States), Franco Biondi (University of Nevada, Reno, United States), Chuanxiu Luo (Chinese Academy of Sciences (CAS), China), Olga Solomina (Institute of Geography (RAS), Russia) and Laura Parducci (Sapienza University of Rome, Italy) for helpful edits on some of the papers. Also, we thank all of the reviewers whose comments and suggestions helped the authors improve their papers.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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