frontiers | Frontiers in Earth Science

TYPE Editorial
PUBLISHED 18 January 2024
DOI 10.3389/feart.2024.1357880

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OPEN ACCESS

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RECEIVED 18 December 2023
ACCEPTED 08 January 2024
PUBLISHED 18 January 2024

CITATION
Zarkogiannis SD, Iwasaki S, Clark EG and Guenser P (2024), Editorial: Virtual paleobiology—advances in X-ray computed microtomography and 3D visualization of fossils.
Front. Earth Sci. 12:1357880.
doi: 10.3389/feart.2024.1357880

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Editorial: Virtual paleobiology—advances in X-ray computed microtomography and 3D visualization of fossils

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KEYWORDS

X-ray microcomputed tomography (μCT), virtual paleobiology, virtual paleontology, paleontology-general, paleobiology, X-rays

Editorial on the Research Topic
Virtual paleobiology -advances in X-ray computed microtomography and 3D visualization of fossils

In this issue, the Editors aim to convey the dynamic and evolving nature of the concept of Virtual Paleobiology, capturing the excitement, interest, enthusiasm, and drive that characterize this field. Leveraging the digital nature of X-ray micro-computed tomography (μCT), this approach enables a virtual representation of the analyzed objects. X-ray μCT significantly enhances paleontologists' ability to study and comprehend the biology, evolution, and ecology of organisms, thereby contributing valuable insights to our understanding of the history of life on Earth. The new perspectives offered by μCT into past ecosystems and organism adaptation to environmental dynamics are crucial for advancing our comprehension and prediction of climate and ocean change.

This Research Topic aims to showcase a variety of perspectives of μCT in oceanic and terrestrial paleobiology so as to inspire and promote cutting edge research. It comprises a compilation of original research and methods articles, along with data reports, covering various topics in paleontological research, including virtual paleontology, internal anatomy, taxonomic studies, functional morphology, preservation assessment, paleoecology and taphonomic studies.

Using μCT, Kimoto et al. were able to perform precise bulk density measurements of planktic foraminiferal tests. A notable aspect of their technique lies in the ability to obtain not only nondestructive, highly accurate morphometric measurements of marine calcifiers but also to determine the mass of foraminiferal tests utilizing the X-ray absorption information from the tomographs. This has significant potential to provide quantitative information on the skeletal mass of microfossils in matrices or in situations where microquantities fall below the analytical limits of other techniques.

Similarly, Choquel et al. examined changes in foraminifera calcification resulting from anthropogenic ocean change through the morphological analyses of marine shells acquired via μCT, revealing that modern specimens are thinner and more porous. Their study provided also a post-data routine to analyze entire test parameters such as the average thickness, calcite volume, calcite surface area, number of pores, pore density, and calcite surface area/volume ratio.

Muto et al. demonstrated the power of μCT scanning to resolve biostratigraphic issues in geological context with high deformation caused by tectonics and/or metamorphism. The authors used tomography to visualise conodont microfossils that are too fragile to be sampled with acid dissolution. In particular, they observe Carboniferous-Permian conodont elements from pelagic siliceous sediments from north-eastern Japan. This allowed the authors to identify index species and correlate the studied section to a relative age and describe a faunal turnover around the Carboniferous-Permian boundary.

A major bottleneck in analyzing marine invertebrates using μCT includes the time it takes to segment individual specimens, as well as challenges with differentiating shelly material from a surrounding calcareous matrix. To facilitate the analysis of fossil invertebrates, Edie et al. applied a deep learning interface to a dataset of shelly calcareous fossil material and demonstrated a high-throughput technique that can be used to cut down specimens' extraction time and even improve the morphological fidelity of manual segmentation or physical preparation.

Jacquet et al. illustrated the utilization of μCT in conducting analyses that would be impractical with destructive sampling techniques. The authors employed tomographic imaging to visualize coprolites of mammalian fauna from the Late Eocene to understand the feeding behavior and identities of their producers. They incorporated 3D imaging along with traditional methods of internal specimen visualization, such as thin-section petrography and SEM. Their μCT data supplemented the other means of data acquisition by revealing the porosity and relative proportion of inclusions, which are metrics not permitted to be calculated by traditional destructive sampling techniques.

Herrera et al. performed a precise three-dimensional (3D) morphological analysis of some extraordinarily preserved Middle Pennsylvanian fossil plants obtained from Mazon Creek. In addition, they analysed the mineralogical composition of the fossil plant remnants using elemental maps and Raman spectroscopy. Their results suggest that the X-ray μCT provided excellent information on the 3D morphological structure of fossil plants but that the quality of the reconstruction may be compromised by the mineral filling associated with fossilization. This is an important suggestion for the high-quality, non-destructive analysis of fossils using μCT, which is expected to develop more in the future.

Frosali et al., delved into the previously unexplored realm of paranasal sinus morphology in canids, focusing on both extant and fossil representatives. Employing innovative deformation-based morphometric techniques, the researchers establish a correlation between frontal sinus morphology and ecomorphotypes in extant canids, supporting the link between diet preferences and sinus development. The study underscores the efficacy of combining morphological inspection and deformation-based geometric morphometrics, paving the way for the study of ecological preferences of other fossil carnivorans. In a similar manner, Duhamel et al. conducted a 3D morphological analysis on the skull of Dicynodontia, one of the most successful Permo-Triassic terrestrial tetrapod clades. Their study allowed the examination of the previously unobservable internal anatomy of the skull, leading to the proposal that the holotype specimen of *Eodicynodon oelofseni* belongs to a new genus.

Lastly, X-ray tomography enables the creation of a novel online database featuring exceptionally well-preserved materials. These high-resolution datasets offer versatile utility across various disciplines. Chen et al. exemplify this concept in their paper, providing three-dimensional morphologies of 40 early Pleistocene planktonic foraminifer tests from the western Pacific Ocean. The authors emphasize the database's diverse applications for studying foraminifer evolution and ecology, along with its potential for taxonomic identification automation through machine learning models.

The current compilation of papers represents just a fraction of what promises to be a continuously expanding and developing subject. In addition, the Editors extend their heartfelt gratitude to all the authors and reviewers who have contributed to this Research Topic. Their dedication and efforts have played a crucial role in shaping the content and quality of this Research Topic. Their work reflects a shared commitment to advancing our understanding of virtual paleobiology and contributes to the ongoing growth and vibrancy of this field.

Author contributions

SZ: Conceptualization, Writing–review and editing. SI: Writing–review and editing. EC: Writing–review and editing. PG: Writing–review and editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

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