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The Megafauna3D Dataset: 3D Models of Late Pleistocene Megafauna Fossils From Uruguay

DATA PAPER

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ABSTRACT

This dataset consists of 3D digital models of fossilised remains from the Pleistocene megafauna of Uruguay, now publicly available for scientists, educators, and the general public. The fossils, housed in collections across Uruguay, were digitised through photogrammetry, structured light, and CT scanning. The dataset includes models of extinct species such as ground sloths, glyptodonts, mastodonts, and a sabre-toothed cat, which played significant roles in the Pleistocene ecosystems. The dataset is stored in the MorphoSource repository under an open licence, allowing for broad reuse in research, education, and public outreach.

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(1) OVERVIEW

CONTEXT

The dataset presented here consists of digitised 3D models of fossils from Uruguay's Late Pleistocene megafauna. During the Late Pleistocene, 129,000 to 11,700 years ago, South America was home to many large mammals, including giant ground sloths, glyptodonts, sabre-toothed cats, and mastodonts. These species coexisted in an ecosystem shaped by glaciations, fluctuating climates, and diverse habitats, ranging from open grasslands to forests. Among the most significant fossils digitised in this project are those from *Lestodon armatus* (a giant ground sloth) and *Smilodon populator* (a sabre-toothed felid), which played critical roles in the megafaunal ecosystems of the region.

Notably, most of the fossils included in this dataset come from the site of Arroyo del Vizcaíno (AdV) in Uruguay, which is of great importance due to the evidence of early human presence [1–2]. The site has yielded bones of different megafauna taxa with surface modifications compatible with human-made cut marks, potentially making it one of the oldest known examples of human-megafauna interaction in South America, dating back as early as ~35,000 years BP [3–4]. This period marks the arrival of the first humans to the continent, who coexisted with the South American megafauna. Thus, understanding the human-megafauna relationships is critical in South American archaeology and palaeontology. The fossils in this dataset provide additional information for studying these interactions and the broader ecological dynamics during this time. At the same time, the abundance of fossil bones and the high representation of taxa at the AdV site allowed the study of different aspects of the Late Pleistocene megafauna of the region, including palaeoecological [5–7], biogeographical [8–11], and evolutionary studies [12–16].

Some of the fossils have been previously used in scientific publications, including Lobato et al. [11], Varela et al. [10], and Varela et al. [17], and have already been deposited in the MorphoMuseuM repository (see [18–20]).

The digitisation of these fossils not only serves as a resource for research into Pleistocene ecosystems but also aids in understanding the causes behind the eventual extinction of the megafauna, which disappeared at the end of the Pleistocene. Climate change and human activities, such as hunting, have been suggested as factors contributing to this extinction event.

Finally, the scans have been part of the palaeontological and outreach project Megafauna3D. The Megafauna3D project combines 3D scanning technology with palaeontological research to increase public awareness and knowledge of extinct megafauna of Uruguay [21–23]. By utilising digitised fossil models, interactive educational tools, and a dedicated web platform, the project aims to engage the public and educational institutions in exploring the country's palaeontological history. In this context, the project is notable for its multidisciplinary strategy, outreach efforts, and the development of educational materials, including a book featuring augmented reality, fanzines, and a teaching box. With emphasis on inclusivity and accessibility, the project encourages public involvement with palaeontological research and advocates for the preservation of fossil heritage [24].

Spatial coverage

Description: Fossil specimens digitised in museums across Uruguay. Figure 1 shows the location of the collections where fossil specimens were digitised. Specimens in the following collections were digitised: Colección Arroyo del Vizcaíno from Canelones; Museo Nacional de Historia Natural, Museo de Historia Natural Dr. Carlos A. Torres de la Llosa, and Facultad de Ciencias from Montevideo; Museo Paleontológico Armando Calcaterra and Museo Municipal de Colonia from Colonia; Museo Paleontológico de Dolores from Soriano; Museo Arqueológico de Río Negro from Río Negro; and Museo de Arqueología y Ciencias Naturales from Salto.

Northern boundary: –30.27522
Southern boundary: –34.96667
Eastern boundary: –53.38583
Western boundary: –58.41667

Temporal coverage

Fossil record from the Pleistocene Epoch (approximately 2.6 million years ago to 11,700 years ago). The age of most of the specimens is considered Late Pleistocene or assignable to the Lujanian South American Land Mammal Age (SALMA; ~129,000–11,700 years ago; [25]).

(2) METHODS

The dataset was created using a variety of 3D digitisation techniques to ensure a high level of detail and accuracy in the 3D models. The fossil specimens were digitised using a combination of photogrammetry, structured light scanning, and computed tomography (CT) scanning. Each method was selected based on the size, complexity, and fragility of the fossils, ensuring the complete capture of the external surface.

STEPS

Photogrammetry: This process involves taking a large number of overlapping photographs from multiple angles around the fossil. We used high-resolution DSLR cameras to capture tens to hundreds of images per specimen, ensuring that every surface was adequately covered. These images were then processed using Agisoft

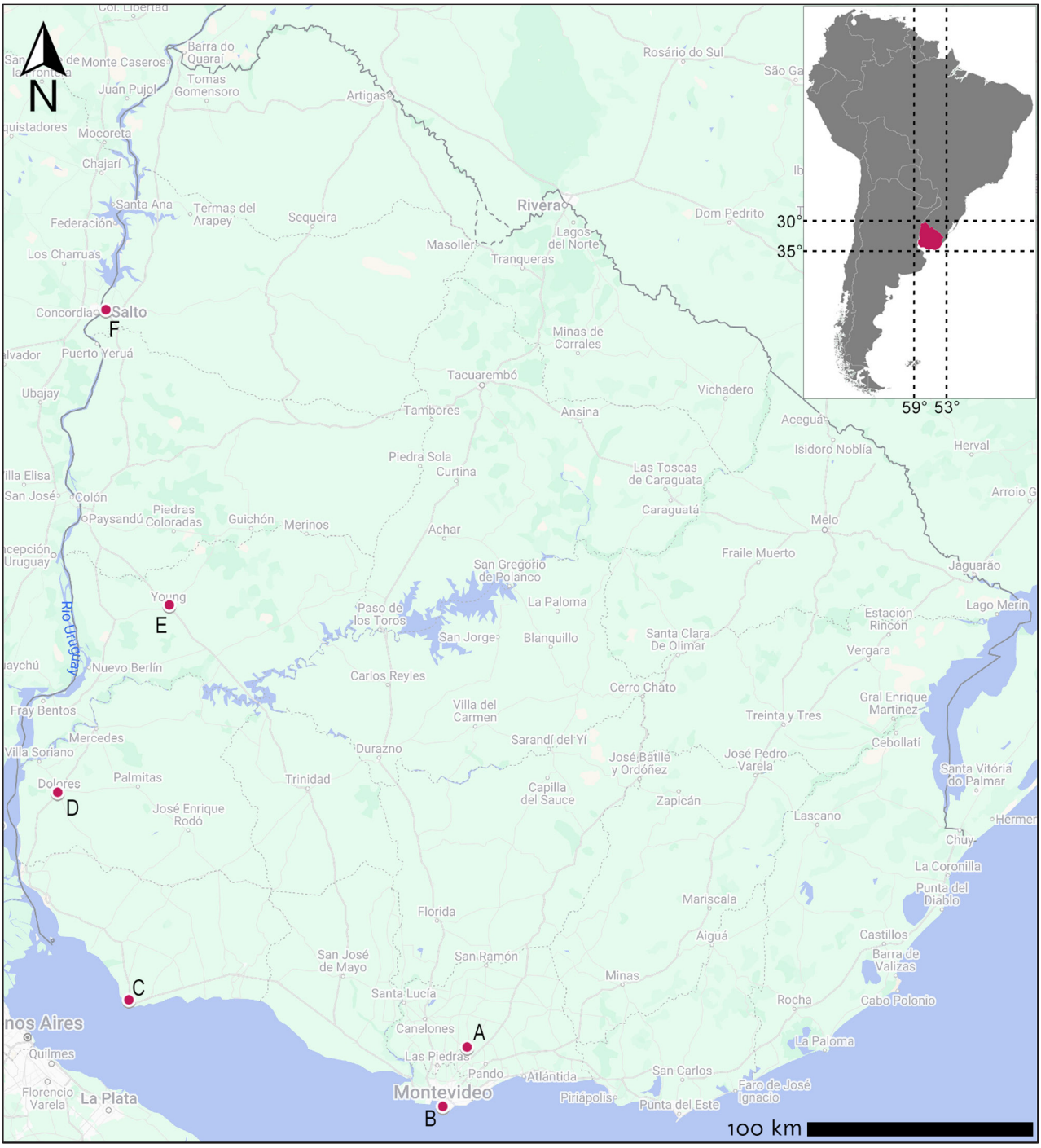

Figure 1 Map showing the location of the collections where fossil specimens were digitised. A: Arroyo del Vizcaíno collection. B: Museo Nacional de Historia Natural, Museo de Historia Natural Dr. Carlos A. Torres de la Llosa, and Facultad de Ciencias from Montevideo. C: Museo Paleontológico Armando Calcaterra and Museo Municipal de Colonia from Colonia. D: Museo Paleontológico de Dolores from Soriano. E: Museo Arqueológico de Río Negro from Río Negro. F: Museo de Arqueología y Ciencias Naturales from Salto.

Photoscan [26], a photogrammetry software that aligns the photographs, generates a dense point cloud, and reconstructs the 3D geometry. This method was used for larger fossils and those with complex surfaces, such as the carapaces of glyptodonts.

Structured Light Scanning: For fossils requiring high geometric detail, such as small or finely textured bones, we used a structured light scanner (specifically the DAVID-SLS-2). This technique involves projecting a known pattern of light onto the fossil's surface and capturing how the pattern distorts across the surface. The captured data were processed using DAVID software to generate an accurate 3D model. Structured light scanning was chosen for fossils where precise surface topography was crucial for understanding features such as delicate anatomical structures.

Computed Tomography (CT) Scanning: CT scanning was employed for a small number of specimens scanned for specific scientific research. CT equipment allowed us to create detailed cross-sectional images of the fossils. The resulting CT data was processed using 3D Slicer [27], enabling us to reconstruct 3D models.

SAMPLING STRATEGY

Fossils were selected based on their completeness and representativeness of different species and skeletal elements. Priority was given to well-preserved fossils (~80% of the scanned specimens) that provide critical insights into Pleistocene fauna from Uruguay and to increase the representativeness of different palaeontological collections. The database comprises a total of 60 fossil specimens covering the following 14 taxa: the sloths *Lestodon armatus*, *Glossotherium robustum*, *Mylodon darwini*, *Valgipes bucklandi*, *Scelidotherium leptocephalum*, and *Nothrotheriops* sp.; the glyptodonts *Glyptodon reticulatus*, *Panochthus tuberculatus*, and *Doedicurus clavicaudatus*; the equid *Hippidion principale*; the proboscidean *Notiomastodon platensis*; the toxodontid *Toxodon platensis*; the ursid *Arctotherium* sp.; and the felid *Smilodon populator*.

QUALITY CONTROL

After the initial scans, all models underwent a post-processing phase. This included refining the meshes and correcting any distortions or holes. The software MeshLab [28] was used to clean up the models and reduce file sizes without sacrificing detail, ensuring that they could be easily handled on online platforms and by educational users. To maintain a high quality standard, the resulting models were cross-checked against the physical fossils to ensure accuracy and regular comparisons between different scanning techniques were performed to select the best method for some fossils.

CONSTRAINTS

The main constraint of the dataset is related to the fact that the scans only represent the surface of the specimens, lacking any internal characteristics. Some limitations in the production of the dataset included the physical condition of certain fossils (example.g., due to preparation or exhibition conditions), which limited scanning angles or the use of the best scanning equipment for very large or fragile specimens. Lighting and environmental conditions during photogrammetry required adjustments, and the acquisition of high-quality textures was not homogeneously achieved, preventing the incorporation of texture data into the dataset.

(3) DATASET DESCRIPTION

OBJECT NAME

Megafauna3D: Late Pleistocene megafauna fossils from Uruguay.

DATA TYPE

Secondary data (3D mesh files) deposited in the MorphoSource repository.

FORMAT NAMES AND VERSIONS

Data is provided as individual STL files for each fossil specimen. The STL format is a widely used for 3D digital files and can be opened by an extensive list of free and open-source software.

CREATION DATES

Most of the fossils were scanned from 2012 to 2018, whereas a more limited number of specimens were scanned from 2018 to 2023.

DATASET CREATORS

LANGUAGE

All the metadata of the 3D models is in English.

LICENSE

The 3D models are distributed with a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International license.

REPOSITORY LOCATION

MorphoSource repository (www.morphosource.org). Permanent identification link: https://www.morphosource.org/projects/000670061/.

PUBLICATION DATE

07/01/2025

(4) REUSE POTENTIAL

The 3D fossil dataset offers significant potential for reuse across multiple domains, including palaeontology, archaeology, education, and public outreach.

In palaeontological research, these 3D models can be used for a wide range of studies, including morphometric analyses, biomechanical simulations, and evolutionary comparisons. Researchers can explore the anatomical details of extinct species in ways that were previously only possible with access to physical fossils, facilitating global collaboration and reducing the need to handle delicate specimens.

For archaeologists, the dataset offers information regarding the megafauna of South America, which can be relevant for exploring questions on the role humans may have played in the extinction of these species. The detailed 3D scans can aid in microscopic and taphonomic analyses.

In education, the 3D models can be incorporated into a wide variety of teaching materials, from elementary school lessons to university-level courses. Teachers and educators can integrate the models into lesson plans, allowing students to interact with them virtually or after printing physical replicas using 3D printers.

Finally, public outreach efforts can use the models to create immersive, interactive experiences for the general public. The open-access nature of the dataset allows for creative uses in virtual museum exhibits and educational apps. Thus, the dataset serves not only as a valuable scientific resource but also as a versatile tool for increasing public understanding and appreciation of palaeontology [29].

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Luciano Varela: 3D scans, data curation, investigation, writing – original draft.
Sebastián Tambusso: 3D scans, data curation, investigation, writing – review & editing.
Martín Batallés: Data curation, visualisation, investigation, writing – review & editing.
Gabriela Costoya: Data curation, visualisation, investigation, software, writing – review & editing.
Richard Fariña: Supervision, funding acquisition, investigation, writing – review & editing.

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