

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed
☐	☒ The exact sample size (<i>n</i>) for each experimental group/condition, given as a discrete number and unit of measurement
☐	☒ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒ The statistical test(s) used AND whether they are one- or two-sided <i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i>
☐	☒ A description of all covariates tested
☐	☒ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☒	☐ For null hypothesis testing, the test statistic (e.g. <i>F</i> , <i>t</i> , <i>r</i>) with confidence intervals, effect sizes, degrees of freedom and <i>P</i> value noted <i>Give P values as exact values whenever suitable.</i>
☒	☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐ Estimates of effect sizes (e.g. Cohen's <i>d</i> , Pearson's <i>r</i>), indicating how they were calculated

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection	Avizo 9 Lite, 3D Slicer (v.4.11.20210226), NIS-Elements D (v.5.41.01), Agisoft Metashape (v.1.8.3), ImageJ (v.1.54f), R package strap 1.6-0, Scotese PaleoAtlas_v3 under fair use for data visualization, and Meshlab (v.2022.02) for digitally segmenting a gastrolith mass.
Data analysis	T.N.T. (v.1.5) for phylogenetic analyses, MrBayes (v.3.7), R package paleotree 3.3.4, Zeiss Xradia 510 Versa 3D high-resolution computed tomography images, R package missMDA (v.1.19), and Smatr (v.3.4-8) for statistical analysis.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

The Zavacephale holotype specimen (MPC-D 100/1209) is repositied in the Institute of Paleontology, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia. The

phylogenetic data matrix is provided as Supplementary Information Data 1. The original data used for the linear morphometric analyses is provided as Supplementary Information Data 2.

Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender

Reporting on race, ethnicity, or other socially relevant groupings

Population characteristics

Recruitment

Ethics oversight

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://www.nature.com/documents/nr-reporting-summary-flat.pdf)

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Here we report the oldest pachycephalosaurian dinosaur, represented by a nearly complete, articulated skeleton from the early Cretaceous Mongolia, shedding light on the early evolution of the cranial dome structure. Morphology, taxonomy, paleohistology, phylogeny, and statistical analyses were performed on the specimen.
Research sample	Our study reports the stratigraphically oldest definitive species of Pachycephalosauria discovered to date and a new species. From the specimen, a histological section was sampled from the tibia for maturity assessments. Cranial elements are CT-scanned to capture internal anatomical structures.
Sampling strategy	The fossil sample was discovered in 2019 field season and collected with permission of Ministry of Culture, Education, and Sciences of Mongolia. The histological sample was sectioned from a tibia, the best preserved weight-bearing limb bone.
Data collection	Linear morphometric analyses include measurements new measurements and those compiled from the published literatures. CT data was collected at the AIF at NC State University. Histological data was processed at the NC Museum of Natural Sciences.
Timing and spatial scale	The fieldwork was conducted in the summer of 2019. The specimen was prepared between 2019 - 2022. CT scan and histological analyses were performed in 2023.
Data exclusions	CT data is accessible to researchers by direct request of the housing institution (IP-MAS)
Reproducibility	All files and information necessary for analytical reproducibility are provided in the main and supplemental text and as supplementary information files, and on Figshare. The holotype specimen of Zavacephale is deposited at IP-MAS, a public repository where it is accessible to qualified researchers. Casts and 3D prints are also housed at NCSM.
Randomization	For the parsimony phylogenetic analysis, we tested the branch support by 5,000 bootstrap replicates.
Blinding	Blinding was not relevant because this manuscript reports a single specimen. The data for linear morphometric analysis was collected from literature and by hand from all available specimens so blinding was unnecessary.

Did the study involve field work? ☒ Yes ☐ No

Field work, collection and transport

Field conditions	The field season 2019 was moderately warm and dry, with extremely high number of small biting flies.
Location	Khuren Dukh, Mongolia: 45° 49' 39"N 108° 26'30"E.
Access & import/export	The fieldwork was conducted under a permit issued by the Ministry of Culture, Education, and Sciences of Mongolia (permit number 2019/09 to T.C.). The fossil was transported to the United States of America for research purpose under a permit issued by the Ministry of Culture, Education, and Sciences of Mongolia and tCustom Clearance after the technical preparation process.
Disturbance	We minimized the landscape change due to quarrying, buried back the quarry once all fossil was recovered, and collected all quarry debris. These actions serve to conserve the natural environment and also protect the fossil rich locality from poachers.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☐	☒ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Palaeontology and Archaeology

Specimen provenance	Bayanjargalan town at the Dundgovi' Province of Mongolia. More detail information on specimen provenance is provided in the manuscript.
Specimen deposition	The holotype specimen (MPC-D 100/1209) is deposited at the Institute of Paleontology, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia.
Dating methods	We followed research for the dating of this locality.
☐	Tick this box to confirm that the raw and calibrated dates are available in the paper or in Supplementary Information.
Ethics oversight	The Ministry of Culture, Education, and Sciences of Mongolia approved the fieldwork and the research on the specimen (permit number 2019/09 to T.C.).

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Plants

Seed stocks	Not applicable
Novel plant genotypes	Not applicable
Authentication	Not applicable