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THE MUSEUM OF EVOLUTION (INSTITUTE OF PALEOBIOLOGY, POLISH ACADEMY OF SCIENCES)

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ABSTRACT

The Museum of Evolution of the Institute of Paleobiology, Polish Academy of Sciences, is among the largest, oldest, and historically most significant vertebrate paleontology-oriented exhibitions in Poland. Located in the Palace of Culture and Science in the Warsaw city center, it showcases a wide variety of original fossil tetrapod specimens gathered over more than half a century. Among those, the collection of Mongolian Cretaceous dinosaurs excavated in the 1960s and 1970s by the Polish-Mongolian paleontological expeditions is probably the most impressive and historically significant. Despite the limited space, which allows to show only a fraction of the gathered material, the Museum of Evolution is a must-see place for any paleontologically inclined visitors to Warsaw. The present work is a guidebook for excursion 'Palaeontological and geological collections in Warsaw' during 11th International Cretaceous Symposium Warsaw, Poland, 2022, August 22–26; therefore it concentrates on Cretaceous fossils.

INTRODUCTION

With over 500 exhibited items (Figs 1, 2), including original fossils, casts, models, reconstructions, maps, and visualizations, the Museum of Evolution of the Institute of Paleobiology, Polish Academy of Sciences (PAS), currently exhibits a variety of evolutionary topics to its visitors. Among the Mesozoic tetrapods, taxa from the Triassic of southern Poland and the Cretaceous of Mongolia are the best-represented. The latter were gathered by the employees of the Institute of Paleobiology, PAS, and the PAS Museum of the Earth, during three paleontological expeditions organized in association with the Mongolian Academy of Sciences between 1963–1971 (e.g., Kielan-Jaworowska and Dovchin 1968; Kielan-Jaworowska and Barsbold 1972). The collected materials were published in a ten-volume monograph series (Kielan-Jaworowska 1968, 1969, 1971, 1972, 1974, 1975, 1977, 1979, 1981, 1984) in *Palaeontologia Polonica*. All volumes were subsequently digitized and are now available for free on the publication's website (http://www.palaeontologia.pan.pl/). In accord with the agreement between the Academies (Kielan-Jaworowska and Dovchin 1968), part of the original material was returned to Mongolia after it was prepared and studied and is now housed in the Paleontological Center of the Mongolian Academy of Sciences in Ulaanbaatar, Mongolia.

The geology and correlations of the Late Cretaceous dinosaur-bearing strata of Mongolia were a subject of numerous studies over the years (Gradziński et al. 1977; Jerzykiewicz 2000; Shuvalov 2000; Hasegawa et al. 2009; Eberth 2018; Fanti et al. 2018; Czepiński 2020a; Jerzykiewicz et al. 2021; and references therein). In general, they are subdivided into five partially temporally overlapping formations capturing a gradual change of humidity: the Baynshire Formation (Cenomanian–Santonian, humid), the Alagteeg Formation (Santonian, sub-humid), the Djadokhta Formation (Campanian, semi-arid), the Baruungoyot Formation (Campanian, semi-arid), and the Nemegt Formation (Maastrichtian, humid). Aside from taxonomic diversity, all of these differ somewhat in taphonomic signatures of vertebrate remains (e.g., Jerzykiewicz et al. 2021).


P T J K C
Pleurostoma
Rhizopoterion
Carneithyris subcardinalis
Cymatoceras intrasiphonatum
Eutrephoceras quadrilineatum
Belemnella kazimiroviensis
Hoploscaphites constrictus
Baculites
Rostellana aequecostata
Voltuspina
Pycnodonte vesicularis
Panopea mandibula
Pholadomya decussata
Pholadomya kasimiri
Dunkleosteus
Lissodus*
Ptychoceratodus roemeri
Tiktaalik roseae
Acanthostega gunnari
Ichthyostega stensioei
Metoposaurus krasiejowensis
Cyclotosaurus intermedius
Siphonops annulatus
Proteus anguinus
Salamandra salamandra
Triadobatrachus massinoti
Czatkobatrachus polonicus
Notobatrachus degiustoi
Alytes obstetricans
Rana
Rhinoderma
Limnoscelis paludis
Lisowicia bojani
Ornithorhynchus anatinus
Chulsanbaatar vulgaris
Catopsbaatar catopsaloides
Nemegtbaatar gobiensis
Kennalestes gobiensis
Asioryctes nemegtensis
Zalambdalestes lechei
Deinotherium giganteum
Mammut borsoni
Loxodonta africana
Mammuthus primigenius
Oryctolagus cuniculus
Trogontherium cuvieri
Simiiformes
Paranthropus boisei
Australopithecus afarensis
Australopithecus africanus
Homo ergaster
Homo erectus
Homo neanderthalensis
Homo sapiens
Eomellivora wimani
Crocuta crocuta spelaea
Panthera spelaea
Homotherium nestianum
Smilodon fatalis
Megantereon
Chalicotherium
Stephanorhinus etruscus
Coelodonta antiquitatis
Propalaeotherium hassiacum
Hyracotherium
Hipparion depereti
Equus caballus
Equus stenonis
Merycoidodon
Pinocetus polonicus
Sivatherium hendeyi
Alces alces
Megaloceros giganteus
Gazella
Ovibos moschatus
Smertibos etruscus
Bison bonasus
Bison priscus
Bos primigenius
Bos taurus
Porifera
Mollusca
Lissamphibia
Multituberculata
Proboscidea
Primates
Carnivora
Perissodactyla
Artiodactyla
Mammalia
Sauropsida

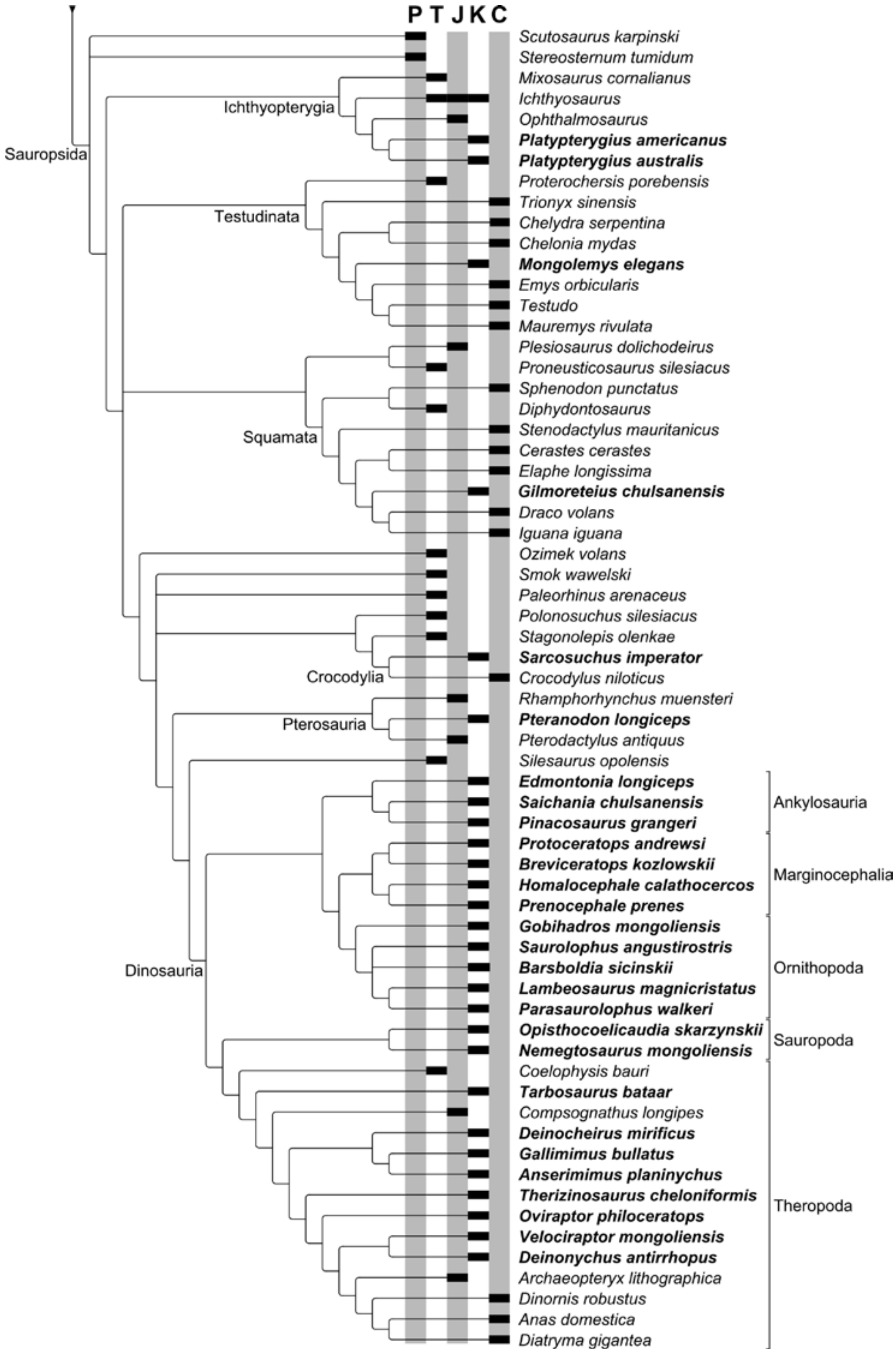

Fig. 2. Phylogeny of animal taxa (Sauropsida) exhibited in the Museum of Evolution of the Institute of Paleobiology, Polish Academy of Sciences, with rough temporal ranges (P, Paleozoic; T, Triassic; J, Jurassic; K, Cretaceous; C, Cenozoic). Composite based on various sources. Cretaceous taxa indicated in bold.

← Fig. 1. Phylogeny of animal taxa (invertebrates and vertebrates except Sauropsida) exhibited in the Museum of Evolution of the Institute of Paleobiology, Polish Academy of Sciences, with rough temporal ranges (P, Paleozoic; T, Triassic; J, Jurassic; K, Cretaceous; C, Cenozoic). Composite based on various sources. Cretaceous taxa indicated in bold. Non-Cretaceous invertebrates (mostly from the Evolution in Oceans exhibition) not shown. * The temporal range of *Lissodus* is extensive, but specimens on the exhibition are of Triassic (Norian) age.

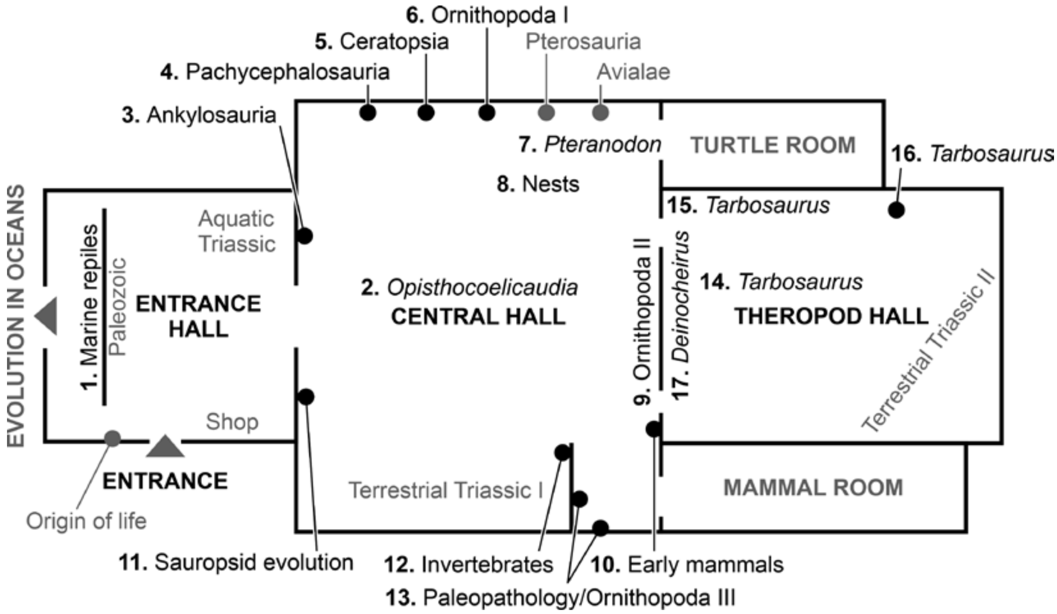

Fig. 3. Schematic map of the Museum of Evolution of the Institute of Paleobiology, Polish Academy of Sciences. Numbers follow the descriptions in the text.

The history of the Museum of Evolution itself started on June 29, 1968 with the opening of an exhibition dedicated to Cretaceous dinosaur finds from the Gobi Desert gathered by the 1960s Polish-Mongolian expeditions. The exhibition had been held in the Palace of Culture and Science (three rooms on the fourth floor) until 1975, when the halls were reclaimed by the Palace and some of the exhibits were transferred to the Zoological Museum (located in the current location of the Museum of Evolution from 1959) of the Museum and Institute of Zoology, PAS, or the PAS Museum of the Earth. The Museum of Evolution was officially established in its current rooms (Fig. 3), taken over from the Museum and Institute of Zoology, PAS, on November 28, 1985. This endeavor was possible thanks to the help of the Museum and Institute of Zoology, PAS (specimens of extant animals), as well as the PAS Botanical Garden in Powsin (financial and formal support). The change of location allowed for an expansion of the scope of the exhibition to include a greater breadth of topics on the evolution of life in a terrestrial setting. Since 2001, the exhibition has been constantly updated and modernized to include, e.g., new finds from the Mesozoic of Poland and updated, detailed life reconstructions and dioramas.

EXHIBITION

The Museum consists of six halls (Figs 3, 4). The ENTRANCE HALL (Fig. 4A) is dedicated to the origin of life, Paleozoic era, the aquatic environment of the Late Triassic Krasiejów locality, and (on the backside of the cabinets to the left of the entrance) marine reptiles (1), including Cretaceous ichthyosaurs (skull casts of *Platypterygius australis* McCoy, 1867 from the Albian Toolebuc and Allaru Mudstone formations of Australia, and *Platypterygius americanus* Nace, 1939 from the Albian–Cenomanian Mowry and Belle Fourche shales of Wyoming, USA; also found in the Albian–Cenomanian Ashville Formation of Canada; Maxwell and Kear 2010). The hall on the left accommodates the newly created exhibition dedicated to marine environments (EVOLUTION IN OCEANS, still under development; Fig. 4B) which currently contains no Cretaceous material. However, poster boards located there present the Albian and Cenomanian faunal assemblage from Annopol, Middle Vistula River section, Poland (e.g., Machalski and Martill 2013; Popov and Machalski 2014; Kapuścińska and Machalski 2015; Bardet et al. 2016; Madzia and Machalski 2017). The locality is unique in Poland in terms of preservation of Cretaceous

Fig. 4. Main halls of the Museum of Evolution of the Institute of Paleobiology, Polish Academy of Sciences: **a** – Entrance Hall; **b** – Evolution in Oceans Hall; **c** – Central Hall; **d** – Turtle Room; **e** – Mammal Room; **f** – Theropod Hall.

marine turtle and pterosaur remains, among others. Cretaceous specimens of interest are mostly located in the halls on the right.

The center of the largest, CENTRAL HALL (Fig. 4C) is occupied by a skeletal reconstruction of a sauropod dinosaur, *Opisthocoelicaudia skarzynskii* Borsuk-Białynicka, 1977 from the Nemegt Formation (Maastrichtian) of Mongolia (2). This species is represented by postcranial remains only and it was suggested that it may be a junior synonym of *Nemegtosaurus mongoliensis* Nowiński, 1971 – a species established based on an isolated cranium from the same formation (e.g., Currie et al. 2018). Following this presumption, the reconstructed skull is based on the latter. However, this interpretation was recently contested (Averianov and Lopatin 2019).

The cabinets along the walls to the left of the entrance document the evolution of sauropsids, mostly Cretaceous herbivorous dinosaurs. The first of those cabinets (3) presents armored dinosaurs (Ankylosauria). The ankylosaurs demonstrate a far-reaching set of adaptations for defense (Hayashi et al. 2010; Arbour and Currie 2015). The most notable specimens are skull casts of *Edmontonia* ('*Panoplosaurus*') *longiceps* Sternberg, 1928 (Maastrichtian St. Mary River and Edmonton formations of Canada; Campanian Judith River Formation and Maastrichtian Lance Formation of the USA; Sternberg 1928; Sahni 1972; Langston 1975) and *Saichania chulsanensis* Maryańska, 1977 (Campanian Baruungoyot Formation and Maastrichtian Nemegt Formation of Mongolia; Late Cretaceous Huiquanpu Formation of China; Arbour and Currie 2016, and references therein). Shown is also a reconstruction (1 : 5) of *Pinacosaurus grangeri* Gilmore, 1933 (Late Cretaceous Alagteeg, Baruungoyot, and Djadokhta formations of Mongolia and Bayan Mandahu and Jiangjunding formations of China) and a cast of the massive tail club of '*Dyoplosaurus giganteus*' Maleev, 1956 (Maastrichtian Nemegt Formation of Mongolia). The latter taxon has a complex taxonomic history but is currently considered a *nomen dubium* (Arbour et al. 2014, 2016).

The next cabinet (4) is dedicated to pachycephalosaurs from Mongolia. Shown are skull casts of *Homalocephale calathocercos* Maryańska and Osmólska, 1974 and *Prenocephale prenes* Maryańska and Osmólska, 1974, from the Nemegt Formation (Maastrichtian) of Mongolia. Although pachycephalosaur remains have been known at least since the early 20th century (e.g., Lambe 1902; Gilmore 1924; Brown and Schlaikjer 1943), the discoveries of the Polish-Mongolian team allowed for proper recognition of this bizarre group of dinosaurs and a much-improved understanding of their anatomy.

In the subsequent cabinet (5), exhibited are skulls, teeth, and a reconstruction of a nest of the most common Mongolian ceratopsian ('horned dinosaurs', albeit this form lacks horns), *Protoceratops andrewsi* Granger and Gregory, 1923 from the Alagteeg (Santonian) and Djadokhta (Campanian) formations of Mongolia. A historical reconstruction of the same species is presented close to the cabinet. For comparison, a little, juvenile skull of *Breviceratops kozlowskii* (Maryańska and Osmólska, 1975) from the Baruungoyot Formation (Campanian) of Mongolia is also shown. *P. andrewsi* is a relatively small and underived representative of the Ceratopsia compared to its much larger and more impressive, horned, mostly North American relatives. This possibly allowed young individuals to facultatively attain a bipedal stance (Słowiak et al. 2019). *B. kozlowskii* was initially described as a species possibly belonging to the genus *Protoceratops* and only later moved to its own genus by Kurzanov (1990). The distinctiveness of that species was questioned as it was suggested to be synonymous with *Bagaceratops rozhdestvenskyi* Maryańska and Osmólska, 1975 (Sereno 2000) but, according to newer studies, it should be considered valid (Czepiński 2020b).

The first of the cabinets containing specimens of ornithopods is next (6), with the skull cast, mandible, and pelvis of *Saurolophus angustirostris* Rozhdestvensky, 1952, from Mongolia. All the ornithopods in the Museum belong to Hadrosauria (duck-billed dinosaurs). Hadrosaurs were a common component of the Cretaceous faunas and played the role of medium-sized to large herbivores. Independently from ceratopsians, they developed an effective food processing mechanism using batteries of numerous small teeth. Although this is frequently overlooked, the largest specimens could reach colossal sizes and even rival some sauropods in terms of body mass – curiously, large, derived representatives of both groups evolved a similar developmental strategy of prolongation of the continuous (with no seasonal cessations) stage of growth (Słowiak et al. 2020).

The hadrosaur cabinet is followed by two cabinets presenting Jurassic pterosaurs and the dinosaur-bird transition. Above, suspended from the ceiling, is a reconstruction of a Cretaceous pterosaur, *Pteranodon longiceps* Marsh, 1876 (7). Vis-à-vis the wall cabinets, presented are casts of dinosaur nests and eggs from the Cretaceous of Mongolia (8) – one of the nests attributed to *Oviraptor philoceratops* Osborn, 1924 from the Djadokhta Formation (Campanian). The TURTLE ROOM (Fig. 4D) located further along this wall accommodates an exhibition of the Late Triassic (Norian) turtles *Proterochersis porebensis* Szczygielski and Sulej, 2016 from Poręba, Poland.

On the wall opposite the entrance to the central hall (9), presented are casts of the skull of *Lambeosaurus magnicristatus* Sternberg, 1935 and the skeleton of *Parasaurolophus walkeri* Parks, 1922 from the Dinosaur Park Formation (Campanian) of Canada, as well as an original fragmentary skeleton (part of the holotype) of *Barsboldia sicinskii* Maryańska and Osmólska, 1981 from the Nemegt Formation (Maastrichtian) of Mongolia. All three dinosaurs are large hadrosaurs. *L. magnicristatus* and *P. walkeri* show elaborate head crests characteristic for derived hadrosaurs from the subfamily Lambeosaurinae, in contrast to crestless or small-crested Saurolophinae. The phylogenetic affinity of *B. sicinskii* is uncertain, because this species is known only from a partial postcranial skeleton, but it was variably interpreted as either a lambeosaurine (Maryańska and Osmólska, 1981) or saurolophine (Prieto-Márquez 2011).

In the cabinet to the right (10), exhibited are casts of skulls of minute Cretaceous (Nemegt and Djadokhta formations) Mongolian early mammals. Three of these represent a successful but now extinct lineage of non-therian mammals, the Multituberculata: *Catopsbaatar catopsaloides* Kielan-Jaworowska, 1974, *Chulsanbaatar vulgaris* Kielan-Jaworowska, 1974, and *Nemegtbaatar gobiensis* Kielan-Jaworowska, 1974. For comparison, the eutherian *Asioryctes nemegtensis* Kielan-Jaworowska, 1975, *Kennalestes gobiensis* Kielan-Jaworowska, 1968, and *Zalambdalestes lechei* Gregory and Simpson, 1926, are also exhibited. An enlarged (10 : 1) model of a skull of *Chulsanbaatar vulgaris* is displayed below the fossils. The multituberculates appeared in the Middle Jurassic (Averianov et al. 2021) and survived until the Eocene (Sloan 1966).

Along the wall to the right of the entrance, there is a cabinet containing, among other reptiles, a shell of *Mongolemys elegans* Khosatzky and Młynarski, 1971, a Late Cretaceous Mongolian turtle, compared with the extant mud turtle, *Eymys orbicularis* (L.). Exhibited is also a cast of the holotype of *Gilmoreteius* ("*Macrocephalosaurus*") *chulsanensis* Sulimski, 1975, a lizard from the Baruungoyot Formation (Campanian) of Mongolia (11).

Further away, next to cabinets and a large diorama presenting terrestrial fauna of the Polish Late Triassic, there is a cabinet with Late Cretaceous marine invertebrates from the Middle Vistula River section (12). Included are sponges (*Pleurostoma* sp. and *Rhizopoterion* sp. from Nasiłów), belemnites [*Belemnella kazimiroviensis* (Skołozdrówna, 1932)], ammonoids (*Baculites* sp. from Piotrawin; *Hoploscaphites constrictus* Sowerby, 1817 from Wola Piasecka), nautiloids [*Cymatoceras intrasiphonatum* (Łopuski, 1912) from Kazimierz Dolny; *Eutrephoceras quadrilineatum* (Favre, 1869) from Nasiłów], bivalves [*Pholadomya* (*Procardia*) *decussata* (Mantell, 1922) from Piotrawin; *Pycnodonte vesicularis* (Lamarck, 1806), *Panopea mandibula* (Sowerby, 1812), and *Pholadomya kasimiri* (Pusch, 1837) from Nasiłów], gastropods [*Rostellana aequecostata* (Favre, 1869) from Kazimierz Dolny; *Volutispina* sp. from Nasiłów], and brachiopods [*Carneithyris subcardinalis* (Sahni, 1925) from Kazimierz Dolny]. Exhibited is also *Lepidenteron lewesiensis* (Mantell, 1922) – a fossil burrow lined with fish remains – from Piotrawin. Some of the exhibited specimens are on loan from the Natural History Museum (branch of the Nadwiślańskie Museum) in Kazimierz Dolny.

Behind the invertebrate exhibit, there is a small exhibition dedicated to paleopathology (13). Of interest are two specimens of the turtle *Mongolemys elegans* showing shell damage and bones of the duck-billed dinosaur *Gobihadros mongoliensis* Tsogtbaatar et al., 2019 from the Baynshire Formation (Cenomanian–Santonian) of Mongolia, presenting deposits of calcium pyrophosphate characteristic of senile individuals (Słowiak et al. 2021). *G. mongoliensis* is a more basal and smaller hadrosaur than the taxa discussed above. However, the specimen on the display is the largest known individual of that species and its maturity is confirmed by significant remodeling of bone tissue. It is one of very few dinosaur individuals known to science that can be positively validated as ontogenetically old. In fact, most dinosaur individuals found thus far died before reaching somatic maturity. The Cretaceous specimens are accompanied by the remains of a Triassic marine reptile with the oldest record of tuberculosis-like infection (Surmik et al. 2018). To the left of the paleopathology exhibit, you will see the entrance to a corridor-like MAMMAL ROOM (Fig. 4E) exhibiting Cenozoic mammals.

The final large hall, the THEROPOD HALL (Fig. 4F), is mostly dedicated to carnivorous

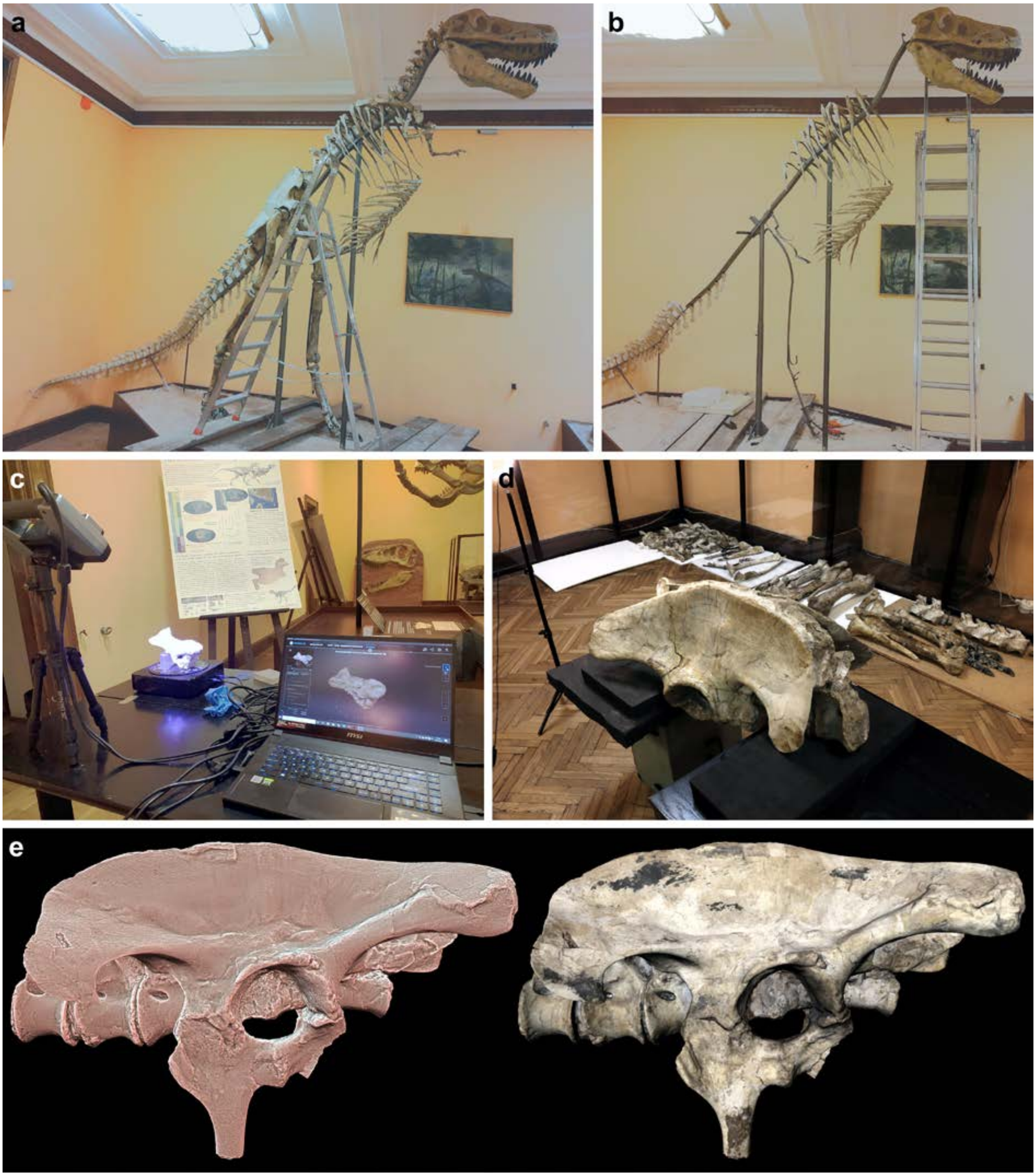

Fig. 5. Digitization of *Tarbosaurus bataar*: **a** – assembled skeleton at the beginning of the works; **b** – the same skeleton, mostly disassembled – remain the restored skull and distal part of the tail and original ribs and gastralia (subsequently disassembled as well); **c** – 3D surface scanning of smaller bones; **d** – pelvis set up for photogrammetry with one of the lights and dismounted vertebrae and limb bones visible in the background; **e** – photogrammetric 3D model of the pelvis with the Radiance Scaling shader enabled to visualize geometric detail (left) and with surface color enabled (right).

dinosaurs. In the center, exhibited is a reconstruction of a skeleton of *Tarbosaurus bataar* Maleev, 1955 from the Nemegt Formation (Maastrichtian) of Mongolia (14), a close relative to the North American *Tyrannosaurus rex* Osborn, 1905. Several original specimens, including the pelvis, hind limb, and mandibles are presented in the same room along with a historical reconstruction of the skull (15). The most interesting is the historical restoration of the skeleton assembled (mostly from original bones, aside from the skull) in the 1960s (16). Noteworthy is its kangaroo-like stance, characteristic for the restorations from that era but corrected in the newer reconstruction. The original, articulated state of the same individual, as found in the field, is captured in the photograph and (after initial preparation) in the cast just next to the restored skeleton; note that the cast is somewhat idealized, and some missing elements are reconstructed. The material of *T. bataar* is currently being studied for a project concerned with postcranial anatomy, variability, and biomechanics of that species ('Functional anatomy of *Tarbosaurus bataar* from the Nemegt Formation of Mongolia'; T. Szczygielski and J. Słowiak-Morkovina). As part of the project, all *T. bataar* material housed in the collection of the Institute of Paleobiology, PAS, including the specimens exhibited in the Museum of Evolution, is being digitized (virtual 3D models of individual bones are created using photogrammetry or 3D surface scanning, Fig. 5). This called for complete disassembly of the original skeleton of *T. bataar* for the first time since 1985 and allowed for its thorough conservation. 3D models created thanks to the project will allow for modernization of that part of the exposition in the following years.

One of the most impressive specimens in the Museum is located between the two entrances to this room – a cast of the gigantic forelimbs of *Deinocheirus mirificus* Osmólska and Roniewicz, 1969 from the Nemegt Formation (Maastrichtian) of Mongolia (17). For a long time, these limbs constituted the only known material of this curious species, making its morphology and relationships enigmatic. Only recently, much of the remaining part of the skeleton, including hindlimbs and the skull, were discovered, finally solving the mystery and allowing to establish the phylogenetic position of *D. mirificus* among the ornithomimosaurs (Lee et al. 2014).

Other cabinets in this hall contain smaller carnivorous reptiles from Mongolia. Among them, exhibited is a hind limb of a smaller relative of *D. mirificus*, *Gallimimus bullatus* Osmólska et al., 1972 from the Nemegt Formation (Maastrichtian) of Mongolia. A life restoration of that species (1 : 2) is also presented in the same hall. The cabinets on the opposite side of the hall show a cast of the skull of a giant crocodile, *Sarcosuchus imperator* de Broin and Taquet, 1966 found in several Cretaceous formations of Algeria, Libya, Niger, and Tunisia (Dridi 2018 and references therein), a model of the skull of the bird-like carnivorous dinosaur *Velociraptor mongoliensis* Osborn, 1924 from the Late Cretaceous of China (Minhe and Zouyun formations; e.g., Young 1958) and Mongolia (Campanian Djadokhta Formation), and the morphological diversity of dinosaur claws. Among the latter, shown is a scythe-like claw of *Therizinosaurus cheloniformis* Maleev, 1954 from the Nemegt Formation (Maastrichtian) of Mongolia. Aside from dinosaurs, a dicynodont and carnivorous archosauromorph remains from the Late Triassic of Poland (e.g., Dzik et al. 2008) are also exhibited.

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