

ZOFIA KIELAN-JAWOROWSKA AND THE GOBI PALAEOLOGICAL EXPEDITIONS

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During an illustrious scientific career that lasted more than 60 years, the late Zofia Kielan-Jaworowska greatly advanced the direction of research in several branches of invertebrate and vertebrate palaeontology. The general public largely knew Zofia as the leader of the famous joint Polish-Mongolian Gobi Expeditions of the 1960s–1970s and the spectacular (mainly dinosaurian) fossils that resulted from those ventures. Indeed, an enduring image that I associate with her name shows Zofia standing beneath one of her discoveries, the enigmatic theropod *Deinocheirus*. Momentous as such finds were, Zofia's principal research area was the phylogenetic relationships of the Mesozoic mammals retrieved during those expeditions, specifically evidence from their brain structure and musculature. It is within this realm that she left her greatest scientific legacy in what had previously been a relatively poorly-developed branch of palaeontology due to the paucity and fragility of fossil material. As well as attaining the forefront of her chosen field, Zofia was a humanist with a unique ability to forge successful collaborations between researchers from the former Council for Mutual Economic Assistance (COMECON) countries and their Western counterparts at a time in history when it was difficult to do so. The inclination to rank Zofia alongside her compatriot Marie Curie (1867–1934) is not only appropriate in terms of the impact each made to science, but the fact that Zofia's late husband was a radiobiologist and that they had spent two years working in Paris is surely more than coincidental. I very much appreciate the opportunity to provide my perspective on the achievements of someone who was both a peerless scientist as well as a scientific leader of her era.

My association with Zofia began as a result of my authorship/co-authorship of popular titles in palaeontology and related fiction literature. The topic of my first monograph was one that was close to her own accomplishments, and I suspect it was this affinity that led her to take a particular interest in the project. The book, *Dragons from the Dunes: the Search for Dinosaurs in the Gobi Desert* (Lavas 1993), was the first popular work to review one century of palaeontological field-work conducted in Mongolia (1892 to 1992). That publication could never have been compiled, nor found its target audience, were it not for Zofia's assistance. I never met Zofia, nor did I in fact even speak to her directly, as all our correspondence was at first by letter or fax, and later via email. However, her responses to my enquiries over the years were always so prompt and helpful that at times it almost seemed as if she was answering from an adjoining office. Some recollections of my correspondence with Zofia are presented in the last section.

BEGINNINGS

Zofia's difficult war-time experiences as a student in German-occupied Poland are detailed in depth elsewhere in this volume (see also Cifelli *et al.* 2015). With all Polish secondary and higher education schools closed during the occupation, I suspect that her unbounded enthusiasm for learning partly stemmed from having to take school lessons at private apartments and later attending clandestine classes given by Warsaw

University. The war also altered her views on the Catholic faith, and she became an agnostic which was very atypical of Polish society at that time. Whilst still at high school she had expressed an early interest in vertebrate evolution and the biological aspects of palaeontology. Following the end of the war, she met the celebrated Polish palaeontologist Roman Kozłowski (1889–1977) who supervised her Masters (1949) and doctoral theses (1953, published as Kielan 1954), both of which concerned Devonian trilobites. Later, under Roman Kozłowski's supervision, she conducted research on Palaeozoic polychaete jaw structure. During a mountaineering field-club trip in 1950, Zofia met Zbyszek Jaworowski, whom she married eight years later.

In her autobiography (Kielan-Jaworowska 2005; see also Kielan-Jaworowska 2013) Zofia mentioned that she had often dreamt of participating in palaeontological field-work in Mongolia ever since reading of the pioneering Central Asiatic Expeditions (CAEs) to Mongolia and China by the American Museum of Natural History, New York (AMNH) from 1922 to 1930. Led by Roy Chapman Andrews (1884–1960) and head palaeontologist Walter Granger (1872–1941), these expeditions retrieved several types of dinosaurs and nests of dinosaurian eggs, the remains of Tertiary mammals and the earliest then-known mammalian skulls (from Cretaceous strata). In 1949 Zofia learned that the Palaeontological Institute of the Russian (at that time, Soviet) Academy of Sciences (PIN) had conducted three major expeditions to Mongolia in 1946 (re-connaissance), 1948 and 1949. Led by the palaeontologist Ivan A. Efremov (1908–1972) and the taxonomist Anatole K. Rozhdestvensky (1920–1983), these expeditions explored even larger sectors of the country and located many new fossil sites containing numerous dinosaurian and mammalian fossils. The most important area was the celebrated Nemegt Valley in southern Mongolia, recognised as one of the world's key Mesozoic fossil repositories.

The subsequent Polish-Mongolian Expedition series took place over three periods; 1963–1965, 1967–1969, and 1970–1971. Together with the CAEs and the Russian Academy of Sciences Expeditions, they comprised the three definitive series of large-scale Gobi field-work of the 20th Century. In his book *Men and Dinosaurs* (Colbert 1968), distinguished American palaeontologist Edwin Colbert (1905–2001) dubbed this period of endeavours as the “Asiatic Dinosaur Rush”. Each series of expeditions had, in their turn, captivated the imagination of scientist and public alike, and this was especially true of Poland where the remains of dinosaurs were previously unknown (that part of Europe having been submerged during much of the Mesozoic, although recent years have witnessed spectacular discoveries of Triassic vertebrates). In fact in 1963, no museum in Poland possessed any dinosaurian remains. Although the Polish-Mongolian Expeditions were followed by subsequent Gobi field-work, notably by the AMNH (beginning in 1990), and the ongoing joint Soviet-Mongolian field-work that began in 1969, none of these would be on such a committed or extensive scale as those of the Asiatic Dinosaur Rush. In order to place the Polish-Mongolian Expeditions in context, the following section includes an overview of the preceding American and Russian field-work in the Gobi.

PIONEERING AMERICAN AND RUSSIAN FIELD-WORK IN THE GOBI

In the 1920s Central Asia held a powerful allure for vertebrate palaeontologists, due to reasons that date from the latter years of the 19th Century. At that time, vertebrate palaeontology had developed to an advanced level in the United States and some European countries, with one of the main topics of debate being the origin of placental mammals (considered as the most successful mammalian group, ahead of the monotremes and marsupials). North American and European Palaeocene strata had yielded a rich placental fossil fauna and yet the older Cretaceous strata were seemingly devoid of them. However, the evolutionary development already evident in Palaeocene mammals suggested that they had been the product of a significant prior history. The consensus was that placentals had originated in some unknown region during the Cretaceous before migrating to North America and Europe. In the early 20th Century the eminent palaeontologist at the AMNH was Henry Fairfield Osborn (1857–1935), and he suggested that the place to search for the earliest placentals was Central Asia. A decade later the AMNH curator William Diller Matthew (1871–1930) advanced a similar view in his influential book *Climate and Evolution* (Matthew 1915). One of the natural historians based at the AMNH at the time was Roy Chapman Andrews. He had organised a zoological collecting expedition to southwest China and the Tibetan border in 1916–1917 and had spent time

collecting in Mongolia on a second expedition in 1919. Andrews was inspired by the arguments of Osborn and Matthew and began promoting a series of elaborate expeditions to eastern Central Asia with the main intention of searching for evidence of early hominids.

The concept of conducting field-work in this part of the world presented a truly daunting prospect. Much of the region is accounted for by the Gobi Desert which forms a vast arc-shaped plateau straddling the high east Central Asian tableland between the elevations of 1600 and 2000 m. A large portion of the Gobi, in turn, falls within the borders of Mongolia, one of the world's largest land-locked countries and also one of the least inhabited. Because of its remoteness, this area remained largely unknown to Westerners as late as the 1920s. Even the origin of the word "Gobi" was lost in antiquity; "Wall of spears", "Desert of Sand" and "Great" are said to be just some of its many meanings in different languages. Due to its acutely continental climate, the Gobi is subjected to greater temperature variations than any other desert (45°C in July to -40°C in January) which effectively excludes the possibility of field-work during winter months. Notable 19th Century explorations in the area included those of Pavlinoff and Matusovski in 1870, Ney Elias in 1872–1873, von Richthofen in 1873 and Nikolay Przhevalsky (1839–1888), the Russian geographer and explorer who led four major expeditions between 1870 and 1885. However, there had only ever been one report of a fossil in the entire area. In 1892 the Russian geologist, explorer and author Vladimir Obruchev (1863–1956) found some rhinoceros teeth on the caravan trail between the Mongolian capital Urga (now Ulaanbaatar) and the Chinese border. In 1902, Colonel Manakin of the Russian Army collected remains of the hadrosaur *Mandschurosaurus* from the Amur River between Russia and Manchuria, with further material being recovered in 1915–1917. Then in 1920, the Russian palaeontologist Aleksei A. Borissiak located a rich fossil deposit near the Aral Sea in Kazakhstan, the geology of which indicated that the Gobi might yield interesting Cenozoic and possibly even Cretaceous fossils. The Kazakh fossils included those of the largest known land mammal, the giant hornless rhinoceros *Indricotherium* (= "Beast of Indrik", a mythical giant animal of Russian folklore) which was only exceeded in size by the largest sauropod dinosaurs.

The CAEs were the most expensive land-based ventures to be organised by the US at that time, costing an estimated \$700,000. Being multi-disciplinary in nature, they included not only palaeontologists, but also geologists, botanists, topographers, and zoologists. As head palaeontologist and scientific coordinator, Walter Granger had valuable experience of fossil collecting in the American West (including the Como Bluff and Bone Cabin quarries) and in the Tertiary strata of Egypt's El Fayum. Other notable AMNH participants were George Olsen, Peter Kaisen, and Albert Johnson. The CAEs were supplied by camel caravans and used special Dodge cars for scouting duties. With their headquarters based at Peking (Beijing), the expeditions made summer forays into the Gobi in 1922, 1923, 1925 (the largest of the series), 1926, 1928, and 1930 (the last three seasons' field work being restricted to areas outside of Mongolia due to political reasons). Granger also organised four winter expeditions to southern and western China during this period. The highlight of the CAEs came in July 1923 at the Flaming Cliffs of Bayn Dzak (Bayan Zag in later publications; Fig. 1) in southern Mongolia. These are eroded buttresses bordering a topographical basin of 18 km diameter. Here, Olsen found the first dinosaurian eggs to be identified (by Granger).

It is often stated that these were the first dinosaurian eggs to be found. In fact dinosaurian eggshells were already known from the French Pyrenees as early as 1859 and almost complete eggs were found in Provence 10 years later (in each case their identity was not confirmed until after the CAE discoveries). Numerous eggs and even large communal nests of eggs were uncovered at Bayn Dzak in close proximity to over 100 skulls and skeletons of the small dinosaur *Protoceratops*, which was originally thought to have laid the eggs (Fig. 2). Also found there was the small theropod *Oviraptor* (= egg thief, because of its association with a nest). Subsequent discoveries in the 1990s indicated that the eggs had in fact been laid by *Oviraptor* and that it was possibly guarding them at the time of burial. Other dinosaurs found by the CAEs include the early ceratopsian *Psittacosaurus*, the ankylosaur *Pinacosaurus*, and the small theropods *Saurornithoides* and *Velociraptor*. While preparing for the 1925 expedition Andrews visited an archaeological excavation of Tang Dynasty tombs north of Urga. These were being supervised by the Russian General Pyotr K. Kozlov, an indefatigable 65 year-old explorer who had actually been an expedition companion of Nikolay Przhevalsky.

In 1925 the CAEs unearthed 10 tiny Mesozoic mammalian skulls or jaws at Bayn Dzak, including the first Cretaceous therian skulls (all were thought to be insectivores and were later placed in four new genera). Political changes within Mongolia restricted the CAE work in the country after 1925, and rising xenophobia in China also impacted on their field-work after 1926. Ironically, the 1930 season produced the largest bulk of fossils, principally those of the Miocene shovel-tusked proboscidean *Platybelodon*. Other Tertiary mam-

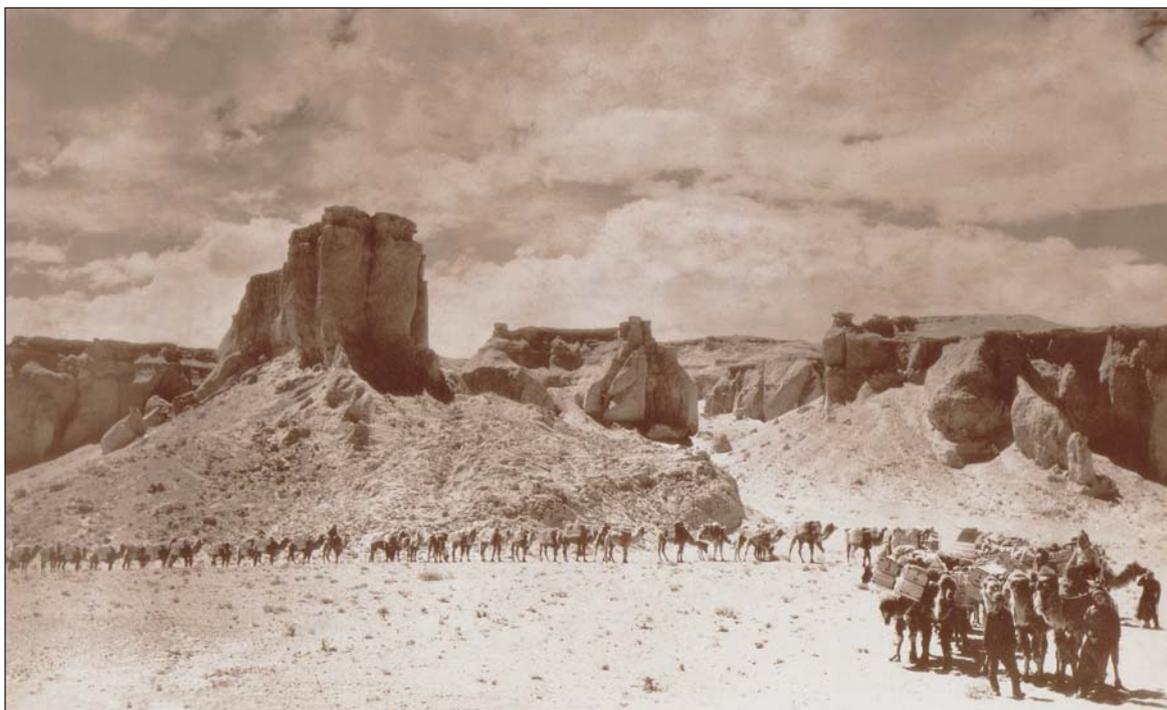


Fig. 1. A caravan of Bactrian camels bearing supplies for the Central Asiatic Expeditions of the American Museum of Natural History, arrives at the “Flaming Cliffs” of Bayn Dzak (known as Bayan Zag in recent literature). J.B. Shackelford; courtesy of American Museum of Natural History Library, neg. 410767.

mal finds included fragmentary remains of titanotheres and indricotheres (the latter from Central Mongolia) and a huge skull of the mysterious Eocene mammal *Andrewsarchus*. Upon reviewing the impressive results of the AMNH field-work, Osborn surmised that the CAEs had only scratched the surface of the Gobi, and that further Mesozoic treasures awaited discovery. Andrews was less optimistic, having written in 1926 that he had likely already exploited the most fossiliferous areas of the country. When he had written this, interest in palaeontology and palaeoanthropology had shifted to other continents, notably Africa due to early hominid finds such as *Australopithecus* (1924).

Although the original palaeoanthropological aims of the CAEs had not been fulfilled, they had been eclipsed by the finds of dinosaurian eggs and Mesozoic mammalian skulls. Results of the CAE field-work were published in the *Natural History of Central Asia* series, *American Museum Novitates*, and *Bulletin of the American Museum of Natural History*. Following Granger’s death in 1941, the AMNH renamed its Asiatic Hall of Fossils as the Walter Granger Memorial Hall. In 1998 Walter Granger’s great-nephew, Vincent Morgan, established the Walter Granger Award, which I designed. Zofia Kielan-Jaworowska was named as the first recipient of this memorial award, which was conferred on 7 November 1998 (the 126th anniversary of Walter Granger’s birth).

Although some authors mention the CAEs and subsequent expeditions being made to “Outer Mongolia”, that name was only valid between 1915 and 1924, after which it became “Mongolia” (or officially the Mongolian People’s Republic). On 11 July 1921, just prior to the first CAE season, a socialist government had come to power in Outer Mongolia as a result of a revolution against Buddhist landowners and Chinese rule. Then in 1931, Japanese forces invaded the neighbouring territory of Inner Mongolia and installed a puppet leader of what was to be known as “Manchuria”. From the early 1920s Mongolia came increasingly under Soviet political and cultural influence, and in 1941 the Mongolian Scientific Commission approached the Soviet Academy of Sciences with a proposition of conducting palaeontological expeditions within the country. The German invasion of the Soviet Union in June 1941 intervened, however, and all negotiations were placed on hold. By 8 May 1945, the war with Germany was over, although the conflict in Asia continued. The Soviet declaration of war with Japan (8 August 1945) was followed by a major Soviet army and naval campaign in Manchuria until the Japanese surrender on 14 August. Negotiations between Mongolia and Russia resumed in 1946 and later that year, the PIN dispatched a reconnaissance expedition to the Gobi. Chief advisor for the expeditions (and participant on the reconnaissance one) was the Director of the Institute (and Academician)



Fig. 2. At Bayn Dzak the Central Asiatic Expeditions found numerous skeletons of the dinosaur *Protoceratops andrewsi* representing a range of sizes. In the same strata were found numerous eggshells and whole eggs that were the first to be identified as being dinosaurian in origin. Bayn Dzak has also yielded important remains of Mesozoic mammals, 50 skulls of which were subsequently removed by the Polish-Mongolian Expeditions during six seasons of field work. (Orlov Palaeontological Museum; courtesy of S.M. Kurzanov and the Russian Palaeontological Institute).

Yuri Orlov (1893–1966), who was a leading authority on mammals and reptiles. The vertebrate palaeontologist Ivan Efremov was chosen to lead each expedition, along with head taxonomist Anatole Rozhdestvensky (aged just 26 at the time). Efremov was already well-known in Russia as a popular science fiction author and had also founded the discipline of taphonomy (the study of fossilization patterns and processes). Other participants included the palaeontologist E.A. Maleev, chief fossil preparator J. Eaglon, the geologist N. Novojilov, and the gifted palaeontologist/zoologist/artist Konstantin K. Flerov, whose lucid reconstructions of prehistoric fauna can be seen at the PIN Museum and the State Darwin Museum in Moscow.

The Russian team entered Mongolia from the north and found that the capital (earlier re-named Ulan Bator) had been transformed into a modern city totally unrecognizable from the village-sized outpost that had greeted the CAEs in the 1920s. Many new buildings lined the city's broad avenues and parks, and the country's first university (Mongolian State University) had recently been founded (1941). Expedition members spent two months on reconnaissance, during which they discovered the vast Nemegt Valley, a huge oblong-shaped basin 180 km east to west and 40–70 km north to south.

The 1948 expedition (Figs 3, 4) included 15 scientific participants plus labourers. Heavy duty ZIL trucks were used to haul supplies and fossil monoliths (specimens encased in blocks of plaster of Paris), while 4WD GAZ field cars were used for observation and scouting work. This mechanization enabled the team to cover greater distances than earlier expeditions, exploring over an arc of more than 1300 km across the country. The first excavations were conducted at Bayn Shireh (eastern Mongolia), where the Cretaceous ankylosaur *Talarurus* was found. Then the team re-visited Bayn Dzak and removed more dinosaurian eggs and associated *Protoceratops* skeletons, as well as the ankylosaur *Pinacosaurus*.

Many dinosaurian cemeteries were located across a broad area of 100 km of the Nemegt Valley, the most important sites being “Nemegt” and “Altan Ula” in the north, and “Tsagan Khushu” in the south. Nemegt Cretaceous deposits produced another ankylosaur (*Tarchia*) and numerous finds of the giant hadrosaur

Saurolophus angustirostris (the mounted skeleton in the Orlov Museum gallery stands 7.6 m tall), and the equally numerous tyrannosaur *Tarbosaurus*, of which seven skeletons were excavated (Fig. 5). At the Dragon's Tomb site were found seven complete *Saurolophus* skeletons and even associated skin impressions. Other Nemegt sites produced incomplete remains of sauropods, ornithomimosaur, and various other small theropods. The most enigmatic finds of 1948 were large forelimb bones and associated gigantic claws (70 cm long). At the time these were misidentified as the remains of turtle-like reptiles (and named *Therizinosaurus* = scythe lizard) but Rozhdestvensky later inferred that they likely belonged to a new "giant sloth"-like theropod. At Lake Orok Noor in 1948, the expedition collected indricothere remains to add to those found by Borissiak. The 1949 PIN expedition included 33 participants and re-traced the 1948 routes as well as venturing to the western borders of Mongolia. Here, at Altan Teli, they located a fossiliferous deposit of Pliocene mammals containing the remains of thousands of animals including the rhinoceros *Chilotherium*, woolly mastodons, ancestors of the giraffe, spiral-antlered antelopes, ancestral horses (*Hipparion*), and numerous rodents. Finally the team returned to earlier excavation sites in the Nemegt Valley and the southeastern Gobi.

The PIN expeditions generally employed a different method of fossil removal and transport to that used by American palaeontologists. A wooden "crate" was built around the fossil and plaster poured into it. Once set, a trench was then dug around the fossil, the "monolith" overturned and the crate completed from the other side. This technique enabled fossils to be transported over very rough ground with reduced risk of breakage. In total some 120 tonnes of monoliths (460 crates) were transported to Moscow, while one of the complete (adult) tarbosaur skeletons was given to the Mongolians to be mounted in the capital's Municipal Museum.

The results of the Russian Expeditions were published in various Russian and Chinese journals including *Trudy Paleontologitscheskogo Instituta*, *Paleontologitscheskiy Zhurnal*, and *Vertebrata Palasiatica*. Efremov provided overviews in *Trudy Mongolskoj Komisii AN SSR* and *Trudy Mongolskoj Komisii Akademii Nauk SSSR* and there were also two popular books; namely Rozhdestvensky's *Hunting for Dinosaurs in the Gobi Desert* (1960; sometimes cited as *In the Footsteps of Dinosaurs in the Gobi Desert*), which was translated into French and German at the time (and subsequently into Japanese), and Efremov's *Road of the Wind* (1956, in Russian). Results of the subsequent long-term Russian field work in Mongolia that began in 1969 can be found in *Transactions of the Joint Soviet-Mongolian Palaeontological Expeditions*.

THE POLISH-MONGOLIAN EXPEDITIONS

Details of the Polish-Mongolian Expeditions are covered elsewhere (see Kielan-Jaworowska 2013), so the following is a brief overview. In 1955 Zofia had travelled to Russia (for the first time) and also to Sweden and Czechoslovakia. In Moscow, she visited the PIN Museum and met Anatole Rozhdestvensky, whom she recalled as a friendly and modest person. He gave her a guided tour of the fossil collections and recounted some of the adventures he and his comrades had experienced in the wilds of Mongolia. The museum housed one of the world's largest palaeontological collections but had an unusual history. During WWII, at the height of the German Army's advance on Moscow, the collections had been dismantled and moved to Alma-Ata for safety, but the museum re-opened again to the public in 1944. It had been the recipient of almost all the Mesozoic and Cenozoic fossils retrieved on the 1940s Gobi expeditions, and photos from this era show halls with scarcely enough room for passage between the exhibits. Further space limitations forced its closure for a time in 1955. In 1966 it was renamed after the institute's former director Yuri Orlov, and in 1972 construction began on another much larger purpose-built museum in southwestern Moscow. This building was declared open in 1987 and remains one of the world's largest (if not the largest) dedicated palaeontological museums.

In 1961 a convention of representatives of the various academies of sciences from the COMECON countries was held in Warsaw. During the proceedings, Roman Kozłowski raised the possibility of further exploitation of the Gobi's vertebrate fossils. The following year, an agreement was signed for an initial three seasons of field work that would involve both Polish and Mongolian palaeontologists. Zofia Kielan-Jaworowska was nominated to lead the Polish side, with Naydin Dovchin leading the Mongolian side. Other participating Polish palaeontologists included Magdalena Borsuk-Białynicka, Teresa Maryńska, Aleksander Nowinski, and Halszka Osmólska, while palaeontologists from the Mongolian side included Demberlyin Dashzeveg, Naydin Dovchin, and Rinchen Barsbold. By this time, the Mongolian capital was served by rail links (the Irkutsk–Ulaanbaatar–Beijing lines) and airlines to neighbouring countries, which meant that all heavy equip-



Fig. 3. **A.** Some participants of the 1948 Russian Gobi expedition (left to right): I. Sidorov, P. Petrunin, N. Brilijv (on truck) I. Alexandrov, Namnandordg, J. Eaglon, I. Efremov, Y. Orlov, I. Likhatchev (on truck), N. Shkilev, N. Vilezhanin, V. Pronin, Damdin. Not present are T. Bezborodov, M. Lookijnova, E.A. Maleev, N. Novojilov, V. Presniakov, and A.K. Rozhdestvensky. **B.** One of the first photographs taken of the famous Nemegt Valley during the 1946 reconnaissance expedition. (From the archives of A.K. Rozhdestvensky; courtesy of S.M. Kurzanov and the Russian Palaeontological Institute).

ment and supplies for field-work could be rail-freighted to Ulaanbaatar, with Zofia and her team flying from Warsaw via Moscow. Nonetheless, as Zofia pointed out to me, her expeditions had to contend with many of the same difficulties as had plagued the logistics and field-work of all earlier expeditions.

The 1963 reconnaissance expedition was supervised by Julian Kulczyki and visited previously-worked sites such as Bayn Shireh, Bayn Dzak, the Nemegt Valley, and nine localities south of Sayn Shand. This was followed by the main seasons' field-work of 1964 (beginning in the south of Mongolia) and 1965. Part of the 1964 season was supervised by Kazimierz Kowalski due to Zofia's commitments to complete her

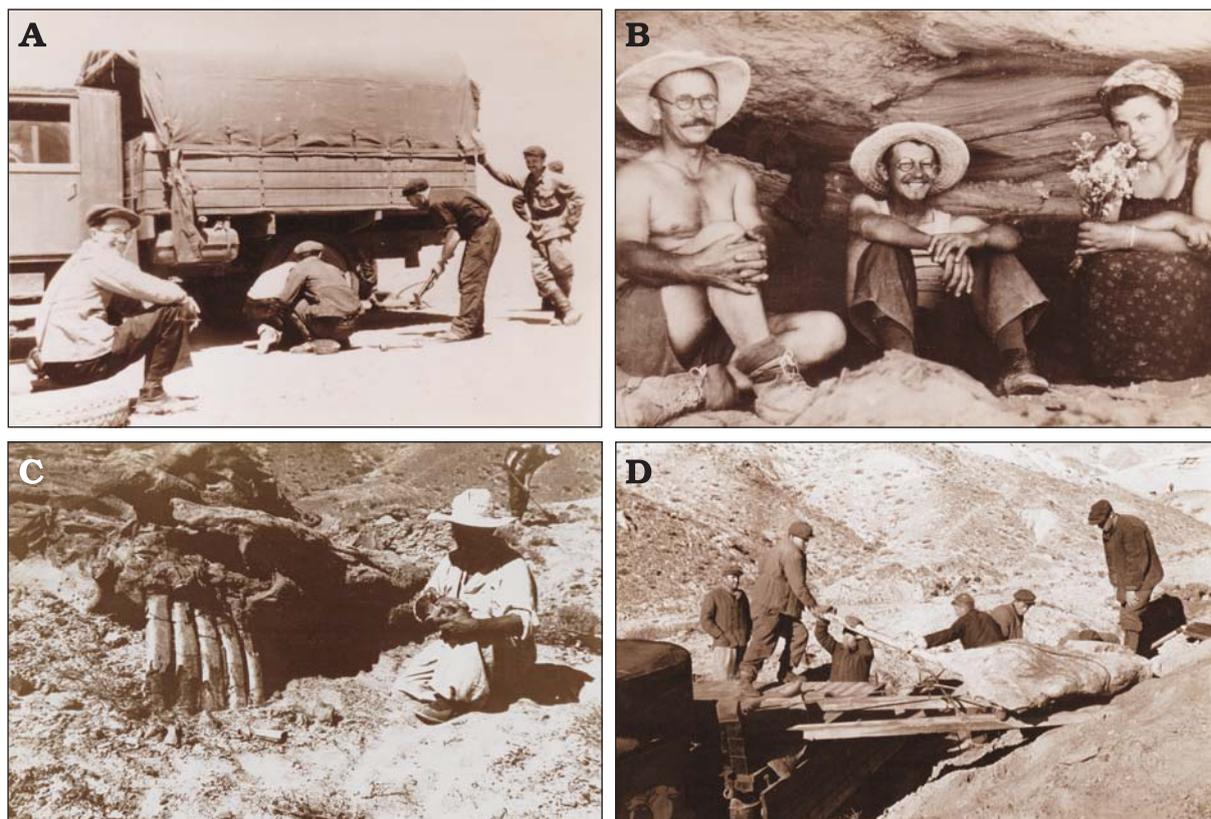


Fig. 4. **A.** Head taxonomist A.K. Rozhdestvensky in the foreground as an expedition truck tyre is exchanged. **B.** Three 1948 expedition members at the Altan Ula locality (left to right): J. Eaglon, A.K. Rozhdestvensky and M. Lookijnova. **C.** Head preparator J. Eaglon at the “Dragon’s Tomb” site with a skeleton of the giant hadrosaur *Saurolophus angustirostris*. **D.** Plaster-encased bones of *Saurolophus angustirostris* being loaded onto a lorry during the 1949 expedition. (From the archives of A.K. Rozhdestvensky; courtesy of S.M. Kurzanov and the Russian Palaeontological Institute).

polychaete research. The 1964 season had 16 participants, while there were 23 in 1965 (counting drivers and extra assistants). In both years, Cenozoic outcrops in central and western Mongolia were explored, including the rich fossil beds of Altan Teli. As in the 1940s, these expeditions used heavy trucks (Polish “Star 66” models) for hauling supplies and crated fossils (other hired vehicles included Tatra, ZIL and GAZ models). Due to the rough desert terrain, the expeditions adopted the monolith technique for removing and transporting fossils. One month of each season was assigned to work at Bayn Dzak, where more dinosaurian remains (*Protoceratops*, *Pinacosaurus*) and eggs were extracted. Work here also yielded over 20 skulls of Cretaceous therian and multituberculate mammals. As Zofia noted in her final book *In Pursuit of Early Mammals* (2013), whilst excavating larger dinosaurs in Mongolia presented logistical difficulties, finding Mesozoic mammalian fossils posed problems at the other end of the size scale; they were very difficult to even see. She found the best way to locate them was with a hand lens while crawling on bandaged hands and knees.

After Bayn Dzak, most of the 1964 and 1965 seasons were spent at Nemegt, but the three smaller expeditions of 1967–1969 were again spent at Bayn Dzak, searching for Mesozoic mammals. In total some 50 Mesozoic mammalian skulls were found during six seasons of field-work at Bayn Dzak. Excavations at Nemegt retrieved six incomplete tarbosaur skeletons, and there were many discoveries of new dinosaurian types including sauropods (*Opisthocoelicaudia* and a skull of *Nemegtosaurus*), large ornithomimosaurs (*Gallimimus*), and the giant forelimbs of the unusual theropod *Deinocheirus*, which Zofia personally discovered. Nemegt also produced further *Saurolophus* remains as well as a lambeosaurine hadrosaur (*Barsboldia*), and skulls and fragmentary skeletons of the first pachcephalosaurs known from this part of the world (*Tylocephale*, *Prenocephale*, *Homalocephale*, and *Goyocephale*). More ankylosaurids (*Tarchia* and *Saichania*) and new protoceratopsians (*Microceratops* and *Bagaceratops*) were added to the collections during the 1970–1971 seasons. The most significant discovery of 1971 was the famous “fighting dinosaurs”

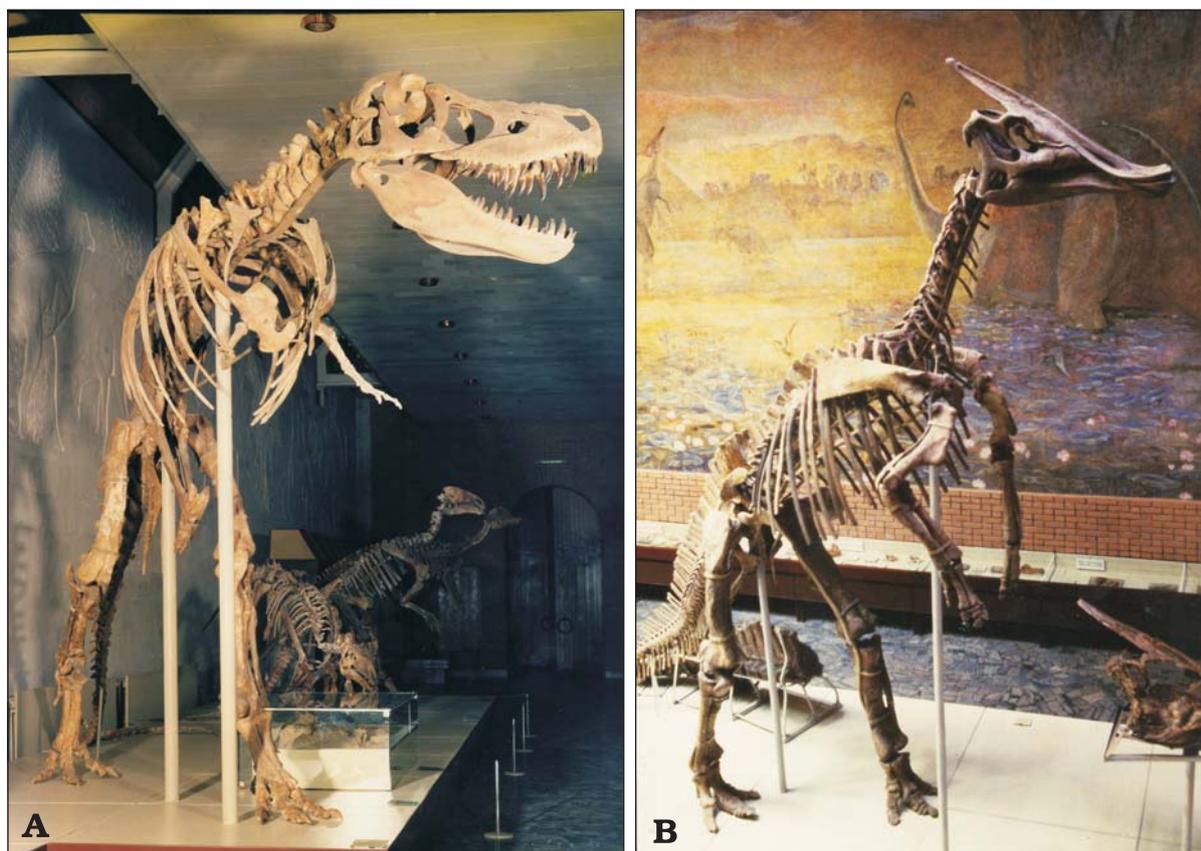


Fig. 5. Dinosaurs recovered from the Nemegt Valley by the Russian Gobi expeditions of the 1940s included *Tarbosaurus* (A) and the hadrosaur *Saurolophus angustirostris* (B). (Orlov Palaeontological Museum; courtesy of S.M. Kurzanov and the Russian Palaeontological Institute).

fossil from Toogreeg (30 km west of Bayn Dzak), where a *Velociraptor* and a *Protoceratops* were found together in a death embrace. This was the first preserved example of mortal combat between dinosaurs.

At the completion of each expedition, the fossils were divided between the Polish and Mongolian partners, the Polish portion being transported to Warsaw by train. Once the scientific descriptions had been completed in Poland, the fossils were returned to Mongolia unless there was more than one specimen of each type, in which case the extra fossils remained in the Polish collections. There were also a number of casts made of unique fossils, such as *Deinocheirus*. The descriptions were published in 10 volumes of *Palaeontologia Polonica* (of which Zofia was editor) between 1969 and 1984, and many of the prepared duplicate or cast specimens were placed on a permanent display called “Evolution on Land” in the Warsaw Palace of Culture. Another more public manifestation of the results of the expeditions was an impressive outdoor park at Chorzow (Silesia) which featured life-sized restorations of Gobi dinosaurs (Fig. 6). These cleverly-fashioned concrete constructions were designed by the expeditions’ technician Wojciech Skarżyński who was descended from the family of famous Polish painters Juliusz Kossak and Wojciech Kossak.

The Polish-Mongolian Expeditions are considered by the scientific community to be one of the most important palaeontological ventures ever undertaken (Kielan-Jaworowska 2013), and they coincided with renewed academic interest in aspects of dinosaurian physiology, ethology, and theropod-avian relationships. They influenced such research by augmenting and re-evaluating the discoveries of earlier expeditions, adding new taxonomic groups to the known Mesozoic fauna, and providing evidence of dinosaurian phylogeny, ontogeny, ecology, and life-habits (Lavas 1993). The expeditions had an even greater impact on the study of Mesozoic mammals; in 1963 the world total of Mesozoic mammalian skulls or jaws was only one dozen specimens. The Polish-Mongolian Expeditions added no fewer than 150 new specimens, some with associated (and extremely rare) postcranial remains. Such fossils not only re-defined subsequent research on early mammals but also clarified the classification of existing specimens (Cifelli *et al.* 2015). During her career, Zofia authored or co-authored around 220 publications, including seven books, most of which concerned Mesozoic mammals.

PERSONAL REFLECTIONS

In the 1980s I assembled a large collection of technical papers on archosaurs dating from the dinosaur renaissance era of the 1960s–1980s, with the intention of compiling a popular review on the topic. My original interest in the Gobi had been inspired many years earlier by Edwin Colbert's (1968) book *Men and Dinosaurs*. In chapter eight, Colbert presented a narration of the CAE field-work as well as a shorter but tantalising review of the Russian expeditions. At that stage, the Polish-Mongolian Expeditions were still underway and Colbert's summary of them was thus very brief. Then I read the English language version of Zofia's popular book *Hunting for Dinosaurs* (Kielan-Jaworowska 1969). This edition outwardly appeared rather inconspicuous with its soft-cover and non-descript jacket, but I was totally captivated as soon as I read the opening paragraphs. Zofia's first-hand account not only contextualized the previous American and Russian expeditions, but her evocative writing style successfully conveyed the remoteness, difficulty and romance of working in such an exotic region so far from civilisation. I also read Roy Chapman Andrews' books *On the Trail of Ancient Man* (1926) and *The New Conquest of Central Asia* (1932), and eventually managed (via circuitous means) to source the two popular non-English titles on the Russian expeditions (Rozhdestvensky's 1960 *Chasse aux Dinosaures dans le Desert de Gobi; les Aventures d'une Expedition Sovietique* and Efremov's 1956 *Road of the Wind* [in Russian]).

In September 1982 I wrote to Zofia seeking advice on whether a popular review of archosaur research might have publication potential. In October I received a reply from the Institute of Paleobiology, Warsaw, informing me that Zofia was in Paris until the end of September 1983, and that my letter had been forwarded to her. Zofia soon replied to me; she was impressed with the compilation and thought it had valuable content, but suggested that there might be more publication potential should I decide to write a popular book using existing material for the technical content. I followed her advice and contacted a number of palaeontologists who had worked in the Gobi, one of whom was Sergei M. Kurzanov of PIN (based at the Orlov Museum). I told him of my project and lack of access to material from the Russian expeditions of the 1940s, which were very poorly-known in the West. Fortuitously, he was able to assist in this regard by selecting numerous photos and negatives from Rozhdestvensky's archives, as well as material from more recent Russian field-work. He also organised for various exhibits at the Museum to be photographed on my behalf.

Throughout the compilation of the book, which took a decade, I corresponded intermittently with Zofia. Amongst other things, she sent me reprints of her technical papers, the volumes of *Palaeontologia Polonica* containing narratives of the Polish-Mongolian Expeditions, peripheral popular material, and a copy of her curriculum vitae. She told me of the life-sized dinosaur reconstructions at Chorzow and sent photos of the models. In May 1990 the bulk of the manuscript was completed and was sent to her for evaluation. By this stage, Zofia and her husband had moved to Norway where she had accepted the position of Professor of Palaeontology at the University of Oslo (in 1987). In July 1990, Zofia wrote back to say that she had read large sections of the manuscript with a keen interest (including the sections of non-expedition content). She also included several pages of helpful detailed corrections relating to historical and taxonomic details.

Once the book was printed (mid 1993) I sent Zofia complimentary copies and in September she wrote back with thanks, describing the final work as very detailed and objective in its historical treatment of the various expeditions. Included with her letter were five pages of listed names and contact details of palaeontologists from many different countries. Specific dinosaur specialists were noted, as was anyone who had conducted field-work in the Gobi. This information proved invaluable, as I soon realised that Zofia's endorsement carried a great deal of weight in academic circles. As a result of this the book sold very well, the main audience being palaeontologists and museum libraries, along with public and university libraries.

After 1993 my correspondence with Zofia lapsed for a time after I became involved with a multi-authored volume, *The Complete Dinosaur*, for which I wrote one chapter on the history of dinosaur collecting in Asia (Lavas 1997). There were also research projects concerning Walter Granger to which I contributed text and reconstructions. Our correspondence resumed when I produced two anniversary editions of Sir Arthur Conan Doyle's novel *The Lost World* (Lavas 2002; Lavas *et al.* 2012) and Zofia provided information on one of Doyle's contemporaries, the author Erazm Majewski (1858–1922), who was not widely known beyond Eastern Europe.

When her husband passed away, Zofia described in an email how the garden of her house adjoined the home of her son Mariusz and his young family. She remarked how fortunate she was to have them living so close by at that time. I was aware that she remained academically active because she included me in her

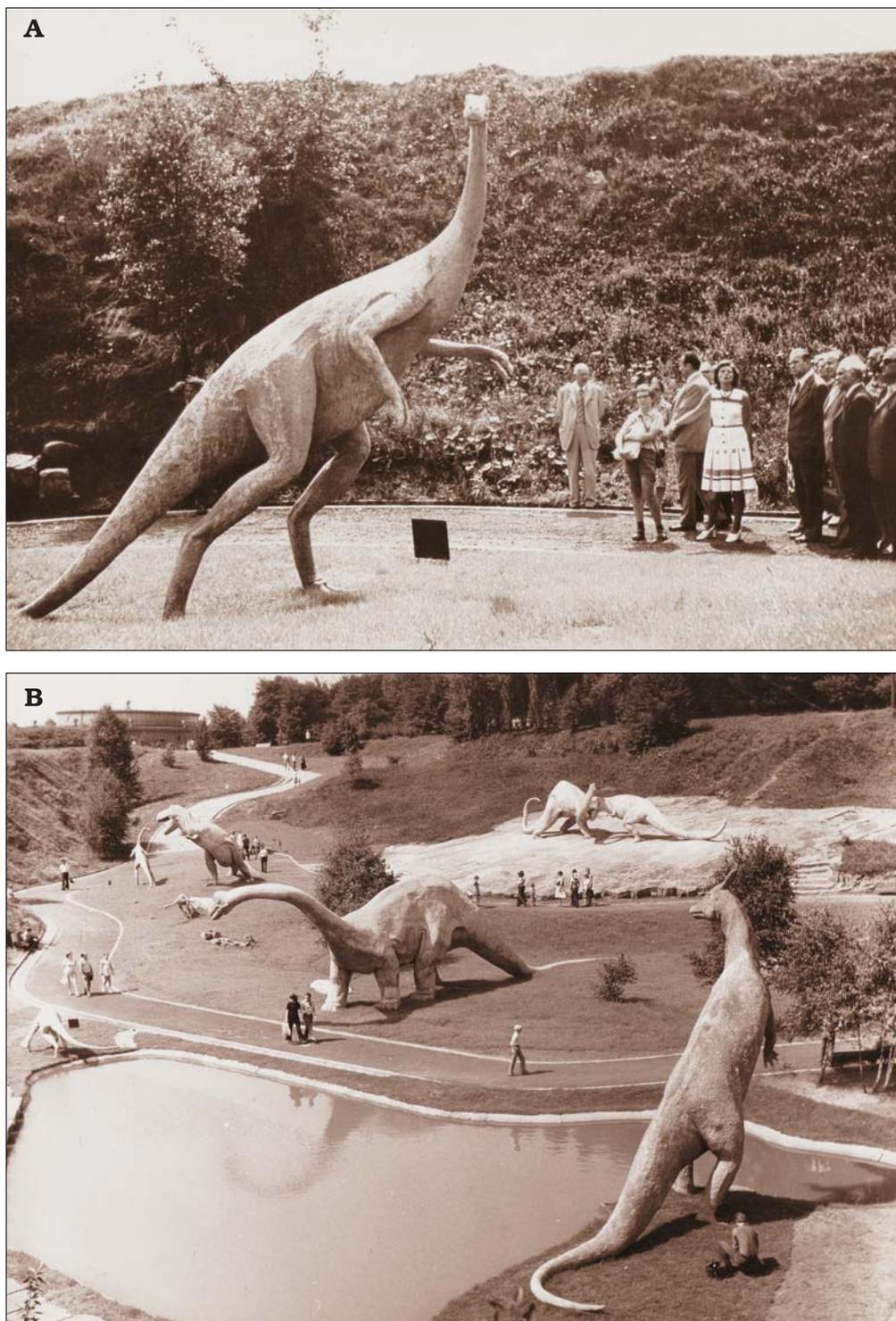


Fig. 6. **A.** Zofia Kielan-Jaworowska at the opening of the dinosaur park at Chorzow, Silesia, with a model of the ornithomimosaur *Gallimimus bullatus* in the foreground. **B.** General overview of the park. (Wojciech Skarżyński; courtesy of Z. Kielan-Jaworowska).

group email updates. Our final correspondence took place in February 2013 after I sent her a copy of *The Lost World Centenary Edition* (Lavas *et al.* 2012) and she arranged for a copy of her book *In Pursuit of Early Mammals* (Kielan-Jaworowska 2013) to be sent to me. In that work she recalled her 2002 return to Mongolia for the first time in 31 years, along with her husband and 10 year-old grand-daughter. They had joined one of the so-called “Nomadic Expeditions” tours which flew tourists from Ulaanbaatar to a small airfield near Bayn Dzak, then drove them directly to the famous Flaming Cliffs. Zofia noted that, far from the remote

and peaceful locality that she had known from her field-work in the 1960s, Bayn Dzak had since become a crowded tourist destination visited by hordes of sightseers. Her group went on to visit some of the famous Nemegt Valley excavation sites where Zofia, ever watchful, even managed to locate a new accumulation of sauropod bones in the easternmost sector (later lamenting that they were unable to expose the skeleton due to limited time and equipment). What had once been a wild and desolate destination only attained by a major expedition in the 1940s was now part of a tourist itinerary. However, some aspects of the trip had not changed over time; the grandeur and beauty of the desert landscape with its solemn lines of deeply-eroded cliff faces, and the friendliness and hospitality of the local Mongol shepherds.

It was with sadness, not to mention initial disbelief, that I happened to see Zofia's obituary in *Nature* (Cifelli 2015) several months after she had passed away. Although I had not heard from her since 2013, she had always seemed so alert and active in previous correspondence that I took it for granted (as I'm sure many others may likewise have done) that she would still be with us for some time yet. By any measure, Zofia lived a truly remarkable life, from her time as a student trying to survive in war-ravaged Poland to eventually becoming the foremost scientist in her field. A very humanistic philosophy enabled her to successfully bring together numerous researchers from both East and West who would otherwise not have had the opportunity of such collaboration. The contributions to this memorial volume bear testament to Zofia's extensive and enduring legacy, not only within professional palaeontology but also to the wider international community.

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