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Hunting Ancient Dragons in China and Canada

Philip J. Currie
Royal Tyrrell Museum of Palaeontology
Drumheller, Alberta T0J 0Y0, Canada

INTRODUCTION

I was eleven years old when I read a book by Roy Chapman Andrews (1953) that changed my life. It was a book about dinosaurs, those magnificent animals that had captured my interest when I was even younger. But more significantly, the book was about looking for the remains of these ancient dragons in the Gobi Desert of China and Mongolia, and for the first time I learned that there was a potential career in hunting dinosaurs. The day I read the book was the day I decided to become a paleontologist. But in my wildest dreams I never imagined that I would follow in the footsteps of Andrews and end up in the Gobi Desert.

The Royal Tyrrell Museum of Palaeontology developed as a concept when I was at the Provincial Museum of Alberta in Edmonton, and was approved for development by the Government of Alberta at the end of 1980. Detailed planning for construction of the building, moving collections and staff, etc., was done in an office in downtown Edmonton. One of our employees, Brian Noble, decided not to move to Drumheller, and we said goodbye to him in mid-1982. But before we parted, he came to me and asked what I would like to do after the museum opened. It was a whimsical question, or so I thought. Without hesitation I told him I wanted to collect dinosaurs in the Gobi Desert. There was the appeal of going to an exotic place from which the excavation of dinosaurs had been so influential on the development of my career. But more importantly, there were sound scientific reasons for wanting to compare the dinosaurs of that region with those I had been collecting in Alberta since 1976.

It has long been known that families of dinosaurs from both the Lower Jurassic and the Upper Cretaceous have representatives in both Asia and North America. However, starting in Middle Jurassic times, there were natural barriers to faunal movements between the northern continents. Nobody is really sure when contacts were re-established, but there appears to have been some faunal interchange in Early Cretaceous times. Between 1930, when the American Museum of Natural History expeditions finished (Andrews 1932), and the mid-1980s, direct comparison of specimens from the two continents was difficult for political reasons. Furthermore, information from central Asia was scanty on the mode of occurrence of fossils, the association of fossil plants and animals, the

structure and composition of the rocks they are found in, and all of the other details that are required to interpret ancient climates, environments and ecosystems. Therefore, one could never be sure whether or not apparent faunal differences were environmentally controlled.

When Brian Noble left our employ, he looked for grants and other forms of support, and started talking to people about the feasibility of working in central Asia. Eventually he established the Ex Terra Foundation, a non-profit organization that was initially set up to promote and develop an expedition to collect dinosaurs in the Gobi Desert. One month after the Royal Tyrrell Museum of Palaeontology opened its doors in September, 1985, we signed an agreement with representatives of the Chinese government.

The expeditions of the Dinosaur Project (China-Canada-Alberta-Ex Terra) were better known as the Canada-China Dinosaur Project. They were operated by staff at the Canadian Museum of Nature (CMN) in Ottawa, the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) in Beijing, and the Royal Tyrrell Museum of Palaeontology (RTMP) in Drumheller, who were to study and compare the dinosaur faunas and their paleoecology in central Asia and North America. This work was sponsored by the Chinese Academy of Sciences, the governments of Alberta and Canada, and the Ex Terra Foundation of Edmonton (who also took an active role in expedition logistics), and was supported by grants from the Donner Foundation (Toronto) and a number of private corporations. The scientific coordinators were Dong Zhiming (IVPP), Dale Russell (CMN) and Philip Currie (RTMP). Other Canadian and Chinese palaeontologists and geologists were brought on to create a multidisciplinary team that included specialists in palynology, invertebrates, turtles, lizards, crocodiles, birds, mammals, dinosaurs, dinosaur footprints and sedimentology. To meet project objectives, we decided to send expeditions to sites in northern China (Xinjjiang and Inner Mongolia), the Canadian Arctic islands (Axel Heiberg, Bylot and Ellesmere), and Alberta (Devil's Coulee, Dinosaur Park, Grande Cache, and Grande Prairie).

The expeditions started in 1986. A survey team visited a site in Xinjiang to assess its potential, and to work out some of the logistics problems. Staff of the IVPP and the Inner Mongolia Museum (Hohhot) came to Canada to join field crews in the Arctic on Axel Heiberg and Ellesmere Islands, and in Alberta. Although no dinosaur bones were discovered in the Arctic, many significant specimens were collected in Dinosaur Provincial Park, including a nicely preserved braincase of the small theropod *Troodon*. Near Grande Prairie (Alberta), the excavation of a bonebed dominated by the remains of the ceratopsian *Pachyrhinosaurus* was started with very promising results.

The first major expedition to China took place in the Junggar Basin of Zinjiang in 1987. At the end of the field season, some of the field crew drove across northern China to investigate potential sites for the 1988 expedition. Four

localities (Bayan Mandahu, Chabu Sumu, Erenhot and Tsagan Nor) were considered to be interesting and productive enough for further investigation, although time constraints restricted major work in future years to Bayan Mandahu and Erenhot. In Canada, the dinosaur egg site at Devil's Coulee was discovered, and fieldwork continued in both Dinosaur Provincial Park and Grande Prairie.

By 1988, the Canadian-Chinese team had been split up into smaller groups so that several sites in China could be worked at the same time. One camp was set up in Xinjiang to continue work on two quarries that had been started in 1987, and to find and collect new specimens. The main camp at Bayan Mandahu amassed a large collection of dinosaurs during the month of June, then moved to Erenhot (Iren Dabasu) in July. Both groups met in the Ordos Basin of Inner Mongolia early in August. Lower Cretaceous specimens proved to be both interesting and highly significant. The 1988 fieldwork in China finished in the Alashan Desert close to a site discovered and worked by the Sino-Soviet expeditions of 1959 and 1960. In Canada, the Canadian Museum of Nature investigated a dinosaur report on Bylot Island in the Arctic, and found enough dinosaur bones to justify another joint Chinese-Canadian expedition the following year. Work continued in Alberta in Devil's Coulee, Dinosaur Provincial Park and Grande Prairie.

The Canada-China Dinosaur Project started the 1989 field program in Xinjiang in May. When this phase was nearing completion, the violent crackdown in Tien-am-men Square in Beijing caused an international furor, and all further field work in China was canceled for the year. Work did continue in Alberta at the same three sites, and the joint expedition to Bylot and Ellesmere Islands in the Arctic was considered to be a success.

The last excavation in Xinjiang was finally completed in 1990, although there was still lots more that could have been collected. The largest field party gathered at Bayan Mandahu in June and early July, and collected many significant specimens and data, and finished mapping our sites. This group moved to Erenhot for the last part of July to excavate a tyrannosaurid skeleton found in 1988, and a major number of nests of dinosaur eggs. A second smaller field party examined sites in the Ordos Basin. In Canada, a major new Lower Cretaceous dinosaur footprint site at Grande Cache produced dinosaur trackways and bird tracks. There was no Chinese participation in any of the other Alberta field sites in 1990, although they joined us again in Dinosaur Provincial Park in 1991.

Work in the Jurassic of China

In 1987, more than forty Chinese and Canadians gathered under the banner of the Canada-China Dinosaur Project to collect dinosaurs in the Middle and Upper Jurassic rocks of the Junggar Basin in northwestern China (Xinjiang). The

site is known as Jiangjunmiao, after the ruins of a desert inn that is one of the few cultural landmarks in the area (Fig. 1). Our Chinese colleagues had worked there in 1984, when they recovered the skeletons of an undescribed large sauropod and a new species of theropod called *Monolophosaurus jiangi* (Zhao and Currie 1993) from the Wucaiwan Formation.

<table>
<tr><td></td><td rowspan="2">Tugulu Group</td><td>Hutubihe Formation</td></tr>
<tr><td>Lower Cretaceous</td><td>Qingshuihe Form.</td></tr>
<tr><td>Upper Jurassic</td><td rowspan="5">Shuixigou Group</td><td>Shishugou Formation</td></tr>
<tr><td>$J_{2,3}$</td><td>Wucaiwan Formation</td></tr>
<tr><td>Middle Jurassic</td><td>Xishanyao Formation</td></tr>
<tr><td>$J_{1,2}$</td><td>Sangongke Formation</td></tr>
<tr><td>Lower Jurassic</td><td>Badaowan Formation</td></tr>
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Figure 1. Stratigraphy of Jurassic and Cretaceous rocks near Jiangjunmiao in Xinjiang, China. The Sino-Canadian expeditions worked mostly in the Shishugou and Wucaiwan Formations, and the lower part of the Tugulu Group.

The Sino-Canadian team excavated several enormous specimens from the Jurassic Wucaiwan and Shishugou Formations of Xinjiang, including the front end of a sauropod (*Mamenchisaurus sinocanadorum*) with cervical (neck) vertebrae up to 1.5 metres (5 feet) long, and cervical ribs as much as 4.1 metres (13 feet) in length. Although the body and tail were not recovered, comparison with *Mamenchisaurus* specimens from southern China suggest the total length of the animal would have been 26 metres (85 feet), which is the largest dinosaur presently known from Asia. The rock, unfortunately, was very hard and it took four field seasons to complete the excavation. Its skull was finally recovered in 1990, and conclusively showed that mamenchisaurids are not closely related to the diplodocids (i.e., *Diplodocus*, *Apatosaurus*) of North America.

A nearly complete skeleton of a well preserved, new species of large theropod was found close to the sauropod skeleton (Fig. 2). Distantly related to *Allosaurus, Sinraptor dongi* was a mere seven metre (23 foot) long carnivore closely related to *Yangchuanosaurus* from southern China.

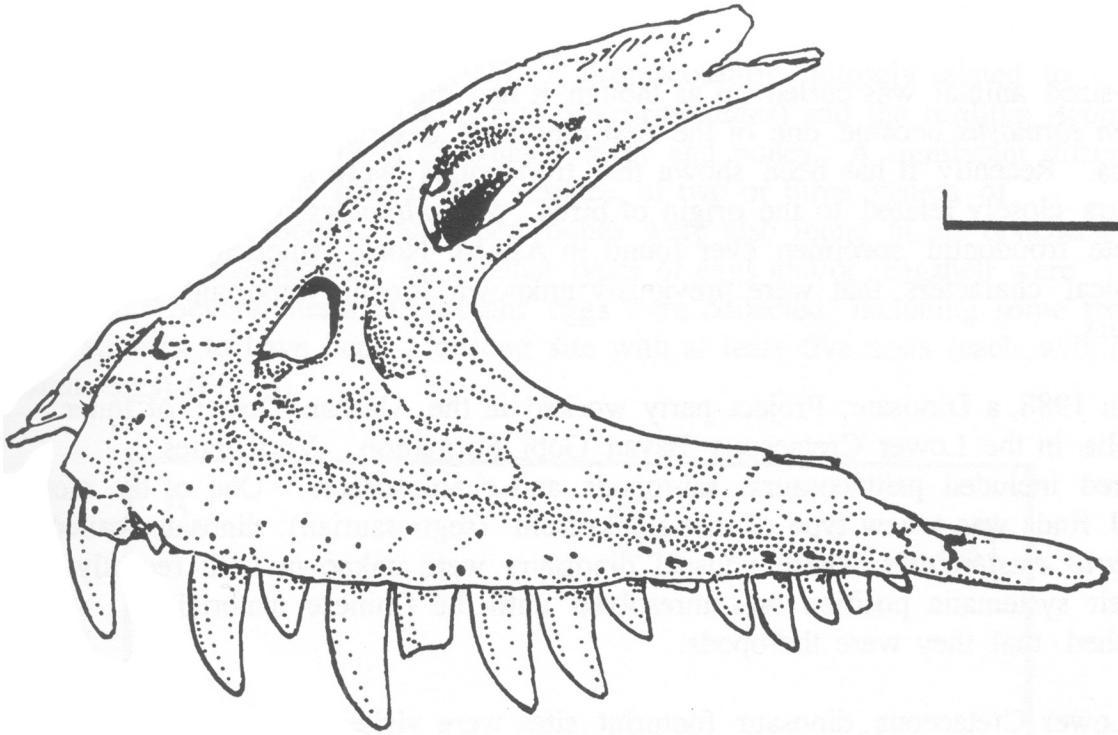

Figure 2. Left maxilla of *Sinraptor dongi*. Scale = 10 cm

The Middle and Upper Jurassic rocks of Xinjiang proved to be very rich, although the hardness of the rock prevented us from removing more than a few of the many dinosaur skeletons that were discovered. Several "fossil forests" were found during the course of the work in Xinjiang, along with numerous specimens of turtles, crocodiles and small herbivorous dinosaurs.

Lower Cretaceous

A great deal of effort was expended at Lower Cretaceous localities in China and Canada to determine when intercontinental faunal exchanges were initiated. The Tugulu Group in Xinjiang produced the abundant remains of pterosaurs, turtles, crocodiles, and small dinosaurs characteristic of the Asian *Psittacosaurus*-pterosaur fauna. In Inner Mongolia, the Ordos Basin has strata of similar age. Here field parties collected many specimens of *Psittacosaurus*, complete champsosaur (*Ikechosaurus sunailinae*) skeletons, and a new species of stegosaur (*Wuerhosaurus ordosi*). One of the new species of turtles recognized in the expedition collections was *Sinemys gamera*, an unusual form with wing-like processes extending from the shell.

The most remarkable find of all the expeditions of the Dinosaur Project was an almost complete skeleton of a small theropod from the Ordos Basin. This

turkey-sized animal was curled up as though it had died in its sleep. In 1856, *Troodon formosus* became one of the first dinosaurs described from North America. Recently it has been shown that troodontids were large-brained dinosaurs closely related to the origin of birds. *Sinornithoides youngi* is the most complete troodontid specimen ever found in Asia or North America, and revealed anatomical characters that were previously unknown for this important family of dinosaurs.

In 1988, a Dinosaur Project party worked in the Alashan Desert of Inner Mongolia in the Lower Cretaceous Bayan Gobi Formation. Vertebrates recovered included psittacosaurs, sauropods and champsosaurs. One of the more unusual finds was a new type of therizinosauroid (segnosaurian) dinosaur called *Alxasaurus elesitaiensis.* These unusual dinosaurs were unknown until recently, and their systematic position was unresolved until the Chinese material established that they were theropods.

Lower Cretaceous dinosaur footprint sites were visited in the Ordos Basin in 1987 and 1990, and in Alberta in 1990 and 1991. The footprint locality near Grande Cache (Alberta) is close in age to the Ordos Basin sites in China, and the footprints are similar in morphology. Unusual theropod tracks (*Buckeburgichnus*) that always have four toe impressions rather than three have been recovered from these widely separated localities. Unfortunately, footprints of similar shape can be made by animals that are not closely related, and therefore the similarity of footprint types only hints at faunal interchange.

In 1986, the Canada-China Dinosaur Project expedition to Axel Heiberg Island failed to find Arctic dinosaurs in the Lower Cretaceous Isachsen Formation. Other types of fossils were collected, however, and helped define the depositional environment of this formation.

Late Cretaceous

Iren Dabasu was the site where Roy Chapman Andrews and other staff of the American Museum of Natural History collected the first central Asian dinosaurs in 1922. Located near the present day border city of Erenhot, little has changed near the place where they camped more than seven decades ago, and the quarries of the expeditions that preceded us were located with relative ease. Because of similarities in the ancient environments, the dinosaur fauna of the Iren Dabasu Formation is closer in some ways to North American dinosaur faunas than to those of other central Asian sites. Both flat-headed hadrosaurid (*Gilmoreosaurus*) and crested lambeosaurid (*Bactrosaurus*) hadrosaurs were found, along with a surprising abundance of the primitive ornithomimid *Archaeornithomimus* . Two species of large carnivores and several small theropods were represented by isolated bones and teeth. A skeleton of the tyrannosaurid

Alectrosaurus was collected in 1990. A dromaeosaurid (closely related to *Velociraptor*), a troodontid (similar to *Saurornithoides*) and the birdlike *Avimimus* were identified on the basis of isolated teeth and bones. A significant difference from North American sites is the presence of two or three genera of therizosauroid theropods. Sauropod bones were also found in the bonebeds dominated by hadrosaurs. Six distinct types of eggs and/or eggshell were identified. Several nests of dinosaur eggs were collected, including some from what appears to have been a nesting site with at least five nests (each with a dozen eggs) (Fig. 3).

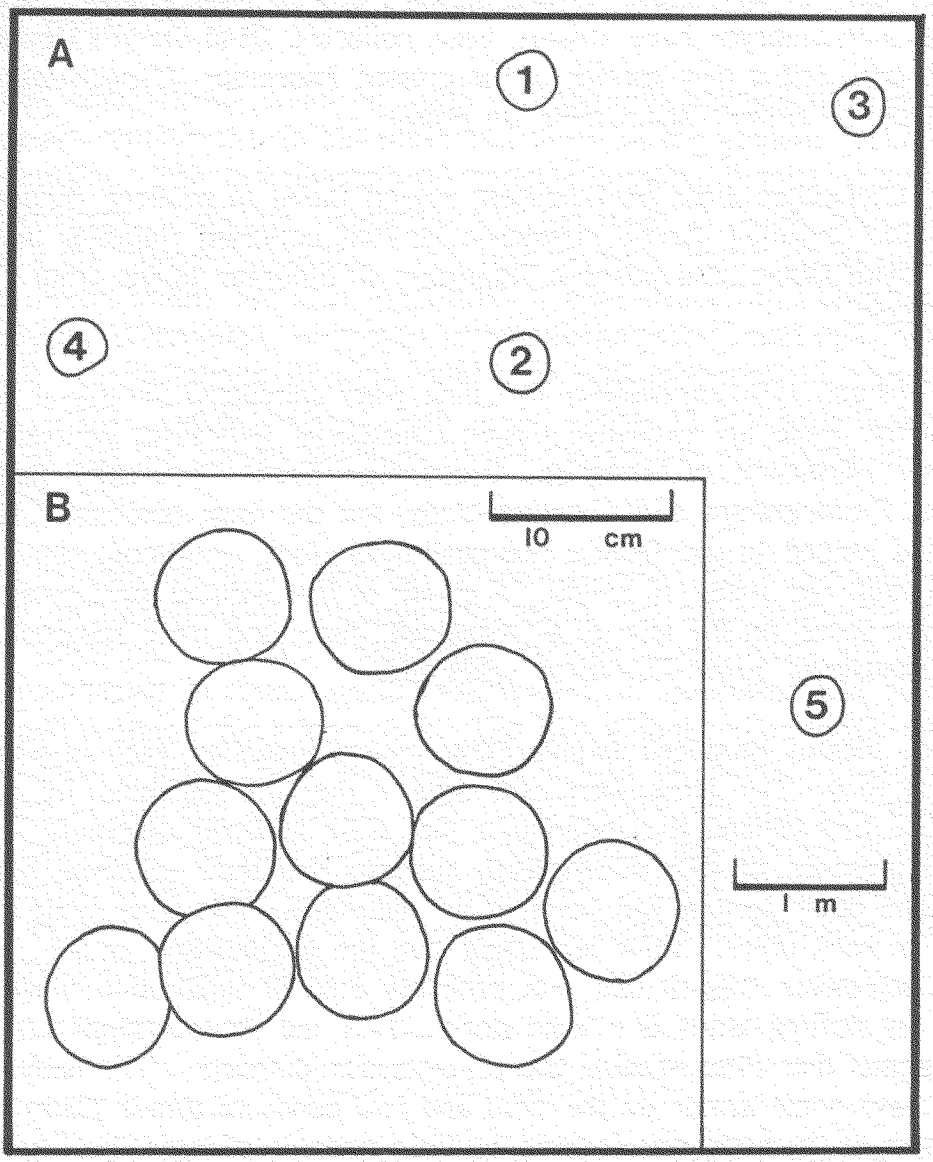

Figure 3. A) Layout of 5 nests of eggs found in the Iren Dabasu Formation at Erenhot, China. Nests 1, 2, 3 were excavated and are in the collections of the Institute of Vertebrate Paleontology and Paleoanthropology, Beijing. Additional nests were present, but were largely destroyed by erosion. B) Map of eggs in IVPP 250790-3, Nest 3.

Most of the collaborative work in Alberta was done in Dinosaur Provincial Park. One of the most significant specimens collected was a braincase of *Troodon* that was described in 1993. Because the semicircular canals, and the air ducts and sinuses associated with middle ear, are well-preserved, it provides information on the transition between dinosaurs and birds. The braincase had been found in 1986 by Tang Zhilu, who distinguished himself by finding a nice *Edmontonia* skull when he returned to the Park in 1991. A bonebed near Grande Prairie, Alberta, produced thousands of specimens, and appears to have been a mass death site. Juveniles and two adult morphs (presumably male and female) have been identified for this new and rather bizarre species of *Pachyrhinosaurus*. Several nests of eggs with embryos have already been collected from Devil's Coulee in southern Alberta, and a new species of the crested hadrosaur *Hypacrosaurus* is being described by Horner and Currie (in press).

Upper Cretaceous beds on Ellesmere Island failed to produce dinosaurs in 1986. The Sino-Canadian Arctic expedition of 1989 collected dinosaur and bird bones from Bylot Island, and possible fragments of dinosaur bones from Ellesmere Island.

The 1988 and 1990 expeditions to China were conducted mostly at Bayan Mandahu, where there are extensive Upper Cretaceous exposures equivalent to the Djadokhta Formation of Mongolia. Protoceratopsians (apparently including *Bagaceratops*, *Protoceratops*, and *Udanoceratops*) are the most commonly recovered dinosaurs, and ranged in size from a two centimeter long embryonic skull to an adult with a skull one meter in length. A group of five parallel protoceratopsian skeletons were found on the side of a "fossilized" dune, and were apparently buried in a sandstorm some 75 million years ago.

Another locality produced twelve *Pinacosaurus* juveniles, each of which were 1.5 m (5 feet) long. Two areas were excavated at the site, separated by 20 meters (66 feet). The first yielded five individuals that were grouped randomly together, although the presence of *Velociraptor* teeth suggests that their gravesite had been disturbed. The other section had seven more individuals that were lying more or less parallel to each other. Their alignment and the composition of the surrounding sediments suggest that they probably died of suffocation when they were buried by shifting sands in a wind storm. Like the *Protoceratops* site, the evidence suggests that *Pinacosaurus* was a gregarious dinosaur. The baby ankylosaurs have some armor on the skull and two bands of armor plates on the neck. The rest of the body was covered by little nodules of bone, but each had a diameter of less than a few millimeters and was obviously just the beginning of a bony plate. So for all intents and purposes the body of a baby ankylosaur was unprotected, and there is no sign of a tail club.

Hundreds of specimens were collected at Bayan Mandahu, and the work of preparing and describing them is still in its early stages. A long legged *Saurornithoides* baby shows how birdlike troodontids looked. *Oviraptor* ("egg thief") received its name because the first skeleton found in Mongolia in 1923 was associated with what were assumed to be *Protoceratops* eggs. The Sino-Canadian expedition in 1990 found a partial skeleton of this theropod associated with a nest of eggs. This time, however, the animal was sitting on top of the nest, suggesting that it may have been incubating and protecting its own eggs. Lizard skulls and skeletons are relatively common at Bayan Mandahu, and specimens found by the Chinese and Canadian team have extended the fossil record of amphisbaenids by 25 million years (Wu et al. 1993).

Direct comparisons could be made between the sedimentary features of the ancient desert represented in the rocks and those of the modern Gobi Desert at Bayan Mandahu. The low diversity of dinosaur species, in spite of a high recovery rate of specimens, is another indication that the rocks at Bayan Mandahu represent a dry paleoenvironment. The type of trace fossils left by insect larvae and other invertebrates are also suggestive of semi-arid to arid climatic conditions. And finally the entrapment of groups of protoceratopsians and ankylosaurs in catastrophic accumulations of sand could only have happened in regions with little vegetation cover. The differences seen in the faunas of this ancient desert in central Asia and the coastal lowlands of the Cretaceous of Alberta are therefore easily understood.

The expeditions of the Dinosaur Project (China-Canada-Alberta-Ex Terra) were large multidisciplinary, multinational teams that were extremely successful in collecting specimens and data. More than 60 tons of specimens are estimated to have been collected in China alone. Preparation of specimens and collaborative research will continue for a long time. The first volume of scientific results has been published (Currie 1993), and other collections of papers will appear in future years. Films and a popular book (Grady 1993) are also available. A traveling exhibition has been assembled using mostly new species of dinosaurs that were collected by the Sino-Canadian expeditions. "The Greatest Show Un-Earthed" was seen by hundreds of thousands of visitors in Edmonton and Toronto in 1993, and starts its Japanese tour in 1994.

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Figure 2 was prepared by Donna Sloan (Royal Tyrrell Museum of Palaeontology), and the others are by the author. The Dinosaur Project (China-Canada-Alberta-Ex Terra) expeditions were sponsored by the Ex Terra Foundation, the governments of Alberta and Canada, and the National Natural Science Foundation of China. Additional support from the Canadian Donner Foundation and Canadian Airlines International is gratefully acknowledged.

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