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Dinosaur

During the 1920s, world attention was focused on the American Museum of Natural History's Central Asiatic Expeditions to collect dinosaurs from the untapped fossil fields of China and Mongolia. Since that time, central Asia has become one of the richest dinosaur-collecting areas in the world, with a full range of fossil evidence from isolated microsites, larger sites, and bonebeds, including footprints, trackways, isolated teeth and bones, complete skeletons, eggs, nests of eggs, and skin impressions. Exceptionally well-preserved specimens from China and Mongolia have provided some of the best information on the anatomy and evolution of major lineages of dinosaurs.

In the heart of Asia, Upper Triassic and Lower Jurassic rocks of continental origin will eventually yield significant dinosaur finds. Middle and Upper Jurassic beds in northwestern China are rich in dinosaur skeletons, and several new species are in the process of being described. The greatest potential for dinosaur finds in central Asia lies in the extent and variety of Cretaceous sites.

Unlike North America and Europe, Asia has a virtually uninterrupted history of terrestrial dinosaur sites. To date, more than 25% of the known dinosaur species have come from central Asia. In addition, because of the number of well-exposed Mesozoic continental deposits with varied depositional environments, many new species of dinosaurs are expected to be recovered.

Major expeditions. The large, multidisciplinary team approach of the American Museum's expeditions was adopted by later multinational expeditions of Americans, Canadians, Chinese, Mongolians, Poles, Soviets, and Swedes.

American Museum of Natural History. The 1922 expedition found the first evidence of dinosaurs in central Asia, a vast, arid, and then largely unmapped region encompassing parts of China, Mongolia, Kazakhstan, and Uzbekistan. The first site at which the fossil evidence was found, Iren Dabasu, near the modern Chinese city of Erenhot, has since been visited by many major expeditions. It has never become a famous locality because most of the thousands of specimens have never been prepared or described.

The American Museum party continued on into Mongolia, where in 1923 it attracted international attention by discovering the first unquestionable nests of dinosaur eggs at a site now known as Bayn Dzak. Here they also recovered more than 75 skulls of *Protoceratops*, one of the best growth series known for any dinosaur and the first to show sexual dimorphism.

A third site in Mongolia (Anda-Khuduk) produced the first specimens of the early ceratopsian *Psittacosaurus*, a dinosaur characteristic of Lower Cretaceous beds across Asia.

In 1990, the American Museum of Natural History initiated a new series of expeditions in Mongolia. A giant lizard capable of eating small dinosaurs as well as the skeletons of several small theropods have already been discovered.

Sino-Swedish and Sino-Canadian expeditions. Sven Hedin's Sino-Swedish expeditions recovered the first Jurassic dinosaur, the long-necked sauropod *Tienshanosaurus*, from Hinjiang in northwestern China. On January 1, 1930, fossils were found in Inner Mongolia near a distinctive pillar of red rock that the team knew as Ulan Tsonchi. The American Museum's expedition had visited the same locality 2 years earlier, and the Sino-Soviet expedition visited in 1960. However, the real importance of this region was realized when, in 1987, a Sino-Canadian expedition found more than 25 skeletons in a single day.

Soviet and Sino-Soviet expeditions. Soviet expeditions into Mongolia in 1946, 1948, and 1949 revisited American Museum localities and discovered new sites, the most notable being the Dragons' Tomb in the Nemegt Valley. The Nemegt has produced an extremely rich Late Cretaceous dinosaur fauna, including well-preserved skeletons of the tyrannosaur *Tarbosaurus* and a giant hadrosaur (*Saurolophus*) that had been previously described from North America. Older dinosaur sites were discovered in the southeastern Gobi of Mongolia in the vicinity of Bayn Shire.

The Soviets collaborated with the Chinese in an ambitious project to collect dinosaurs and other fossils across northern China and central Asia (Kazakhstan, Uzbekistan) over a 5-year period. The Sino-Soviet expeditions got under way in 1959 at the American Museum's Iren Dabasu site. The following year, important new dinosaur sites of Cretaceous age were discovered in the Alashan Desert. The Early Cretaceous site of Maortu produced the iguanodont *Probactrosaurus* and a large theropod. The Upper Cretaceous rocks of Tashuikou yielded a beautiful, virtually complete skeleton of a large ankylosaur. When the political relationship between China and the Soviet Union collapsed in 1960, the Soviets reluctantly returned home. Tons of specimens had been collected, most of which are still in crates in Beijing.

Polish-Mongolian and Soviet-Mongolian expeditions. The Polish-Mongolian Paleontological Expeditions (1964–1971) were extremely successful, revisiting localities worked by Americans and Soviets and pushing into new areas within and to the west of the Nemegt Valley. Small theropods, ornithomimids, tyrannosaurs, sauropods, hadrosaurs, ankylosaurs, and the first good Asian pachycephalosaurs were found. One of the most exciting discoveries was a pair of dinosaurs, *Velociraptor* and *Protoceratops*, that had apparently perished in a death lock.

The longest continuous program in central Asia was the Soviet-Mongolian Paleontological Expeditions (1968–1990), which traversed all of southern Mongolia. Many new dinosaur sites were identified, but the classic collecting sites at Bayn Dzak, Nemegt, and

Bayn Shire continued to produce the best material.

Soviet programs in Kazakhstan and Uzbekistan have been ongoing since the 1920s. Shakh-Shakh, a major locality north of the Aral Sea, produced its first dinosaur skull in 1957. Recently, paleontologists from St. Petersburg and Alma Ata have focused on recovering individual bones from bonebeds and microsites. They have discovered dinosaur faunas that are similar to those from the latest Cretaceous of North America. Large horned dinosaurs of the family Ceratopsidae have been identified for the first time in central Asia.

Sino-Canadian expeditions. The Sino-Canadian Dinosaur Project expeditions (1986–1990), the first to hunt exclusively for dinosaurs, worked in both China and Canada. In Xinjiang, crews collected a new type of large theropod and the neck of the largest sauropod known from Asia. It took four summers to excavate to the end of the neck, where they found the skull, the first known for a mamenchisaur sauropod. In the Ordos Basin, many specimens of *Psittacosaurus* were recovered. In 1988, the most complete skeleton known of a troodontid theropod was uncovered. This find was significant because troodontids have the largest brains among dinosaurs and share many specialized characters with birds, thereby giving clues about the origin of the latter.

The most productive locality, Bayan Mandahu, is 20 mi (32 km) west of the Ulan Tsonchi site. One site revealed a mass death of at least 12 baby ankylosaurs, offering the first evidence that armored dinosaurs were gregarious.

Paleoenvironments. Paleontological, sedimentological, and taphomonic evidence is used to determine what ancient climates and environments were like. Geologists of the 1920s determined that central Asia had been continental since the beginning of the Mesozoic Era, and that many of the best dinosaur-collecting sites were as arid then as they are now. Whereas most regions in the world have preservation biases that favored large dinosaur specimens and destroyed small ones, the arid or semiarid conditions of many localities in central Asia have resulted in preservation of eggs, baby dinosaurs, and complete skeletons of small dinosaurs. An alternative hypothesis suggested that the ancient wind-blown sands were actually dunes on the margins of lakes, and that some of the dinosaurs had been trapped in quicksand.

Sedimentologists from the 1986–1990 Sino-Canadian team tried to resolve which, if either, of these interpretations was correct and whether the Asian dinosaurs had lived in wetland environments like those of most North American sites or in dry regions. Part of the Sino-Canadian objective was to determine the cause of differences between North American and Asian dinosaurs and dinosaur faunas. If the environments had been similar, the differences in anatomy and faunal composition were the result of geographic or temporal separation. However, if the Asian sites had been arid or semiarid, the differences might be correlated with environmental differences.

Sedimentologists with the Sino-Canadian expedition in Asia identified eolian dunes and other features characteristic of a desert. The desert conditions explain the low diversity of species in such Asian sites as Bayn Dzak and Bayan Mandahu, which produce hundreds of dinosaur skeletons, and the generally small size of Asian dinosaurs relative to North American ones. The ancient desert was a stressed environment, and relatively few animals were adapted to living there.

Understanding the environment of places like Bayn Dzak forces a reinterpretation of some of the finds. For example, the pair of dinosaurs *Velociraptor* and *Protoceratops* was once interpreted as being locked in combat when they became trapped in quicksand. It now seems more likely that the *Protoceratops* was attacked and killed by the *Velociraptor* while seeking shelter behind a sand dune during a sandstorm. This pattern of attack is paralleled in the Sahara by hyenas, which are known to attack gazelles under the cover of sandstorms. It appears that the *Protoceratops* locked its jaws on the *Velociraptor*'s arm before dying, resulting in a dual burial in the sand.

The 12 baby ankylosaurs at Bayan Mandahu probably suffered a similar fate. Most of the animals were found oriented in one direction, as if they had aligned their bodies to offer less resistance to a strong wind, like cattle and horses in a rain or snow storm.

The Nemegt sites of Mongolia represent a fluvial environment closer to that of North American sites. The diversity of fossils is much greater than at Bayn Dzak. In fact, there is the same high diversity (35+ species) of dinosaurs at the Nemegt site as at the temporally equivalent Dinosaur Provincial Park in Canada. The faunas of these sites are remarkably similar.

Intercontinental movements. The distribution of dinosaurs, just like those of other animals and plants, are controlled by many factors, including climate and connections between land masses. When dinosaurs appeared, 2.25×10^8 years ago, the continents were still interconnected, allowing plants and animals to spread everywhere, including to Antarctica. But as the land masses pulled apart, the movements of plants and animals were restricted.

The presence of *Dilophosaurus*, a peculiar carnivorous dinosaur with a pair of bony crests on its head, in Arizona and Yunnan (China) shows that these areas were bridged by land during the Early Jurassic. By the Late Jurassic, however, Asian and North American dinosaur faunas seem to have been developing independently. The large carnivorous dinosaurs and sauropods recovered by Sino-Canadian expeditions from the Upper Jurassic rocks of northwestern China are quite different, at the subfamily or family level, from the theropods and sauropods of North America. The differences are still apparent during the Early Cretaceous, when much of central Asia was covered by an extensive series of lakes and *Psittacosaurus* was the most common dinosaur in the region. However, the faunal differences may be attributable to ecological differences rather than continental separation, because at least a few animals seem to be the same in North America and Asia.

Dinosaurs colonized the polar regions and were able to move between the northern continents across Cretaceous land bridges in the Arctic. Most families of Late Cretaceous dinosaurs found in the Northern Hemisphere have representatives in both Asia and North America.

For background information *SEE* CONTINENTAL DRIFT; DINOSAUR; TAPHONOMY in the McGraw-Hill Encyclopedia of Science & Technology.

Philip J. Currie

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Drone

Military leaders have always wanted the ability to see beyond the horizon. This need has led to the development of unmanned air vehicles (UAVs), with a payload of cameras or other sensors. Although reconnaissance was the primary goal of this development, innovative civilian applications have focused on placing scientific payloads at altitudes and for time periods not possible for humans.

The early name for these aircraft, remotely piloted vehicles (RPVs), has largely been abandoned because of the often preprogrammed, or autonomous, nature of their flight control. The class of UAV normally associated with the meteorological research of the atmosphere is the high-altitude long-endurance UAV (HALE UAV). The requirements for this class of air vehicle are unusual and unique.

Scientific investigation of the ozone-depleted and carbon dioxide–rich upper atmosphere require data gathering that can be performed only by high-altitude, long-endurance crewless aircraft. With ongoing developments in airfoil design at low Reynolds numbers and transonic Mach numbers, innovative propulsion systems, lightweight and strong composite materials, and miniaturized instrument packages, a family of aerial platforms will be available to help gather the data necessary for accurate global environmental models.

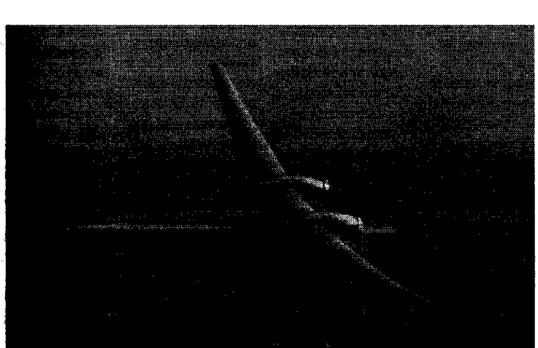

Fig. 1. Boeing Condor UAV. (*Boeing Defense and Space Group*)

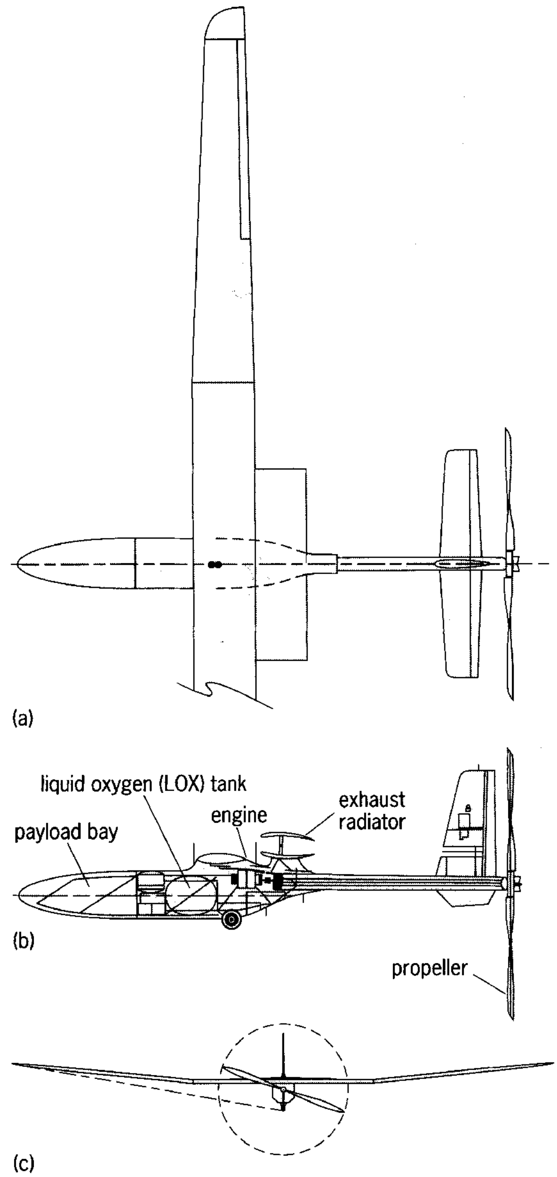

Fig. 2. Perseus UAV. (*a*) Plan view. (*b*) Side view (*after News breaks: Perseus tested in closed-cycle mode, Aviat. Week Space Technol., 137(3):16, July 20, 1992*). (*c*) Aft view (*after AIAA Pap. 91–3162, Aircraft Design Systems and Operations Meeting, Baltimore, September, 23–25, 1991*)

Need for meteorological UAVs. An important factor in understanding the impact of humanity on the global environment is the collection of atmospheric data for accurate modeling of the planetary climate. The accumulation of carbon dioxide and other gases that absorb solar radiation in the troposphere, and the depletion of ozone in the stratosphere, are promoting a measurable and significant change in global atmosphere. Remote measurements made by ground-based sources and space-based platforms such as satellites fail to provide information on the detailed structure of the atmospheric chemistry or dynamics. High-altitude balloons and rockets can make on-site measurements but cannot provide long-term on-station data, nor can they be as easily controlled or maneuvered as low-speed aircraft.

Crewed aircraft have provided most of the atmo-