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Article Summary: Nebraska has a spectacularly good fossil record for the later period of the Cenozoic Era, some 30 million years ago. The Chadron Formation in the badlands of Nebraska and South Dakota continues to reveal skeletons of previously unknown species.

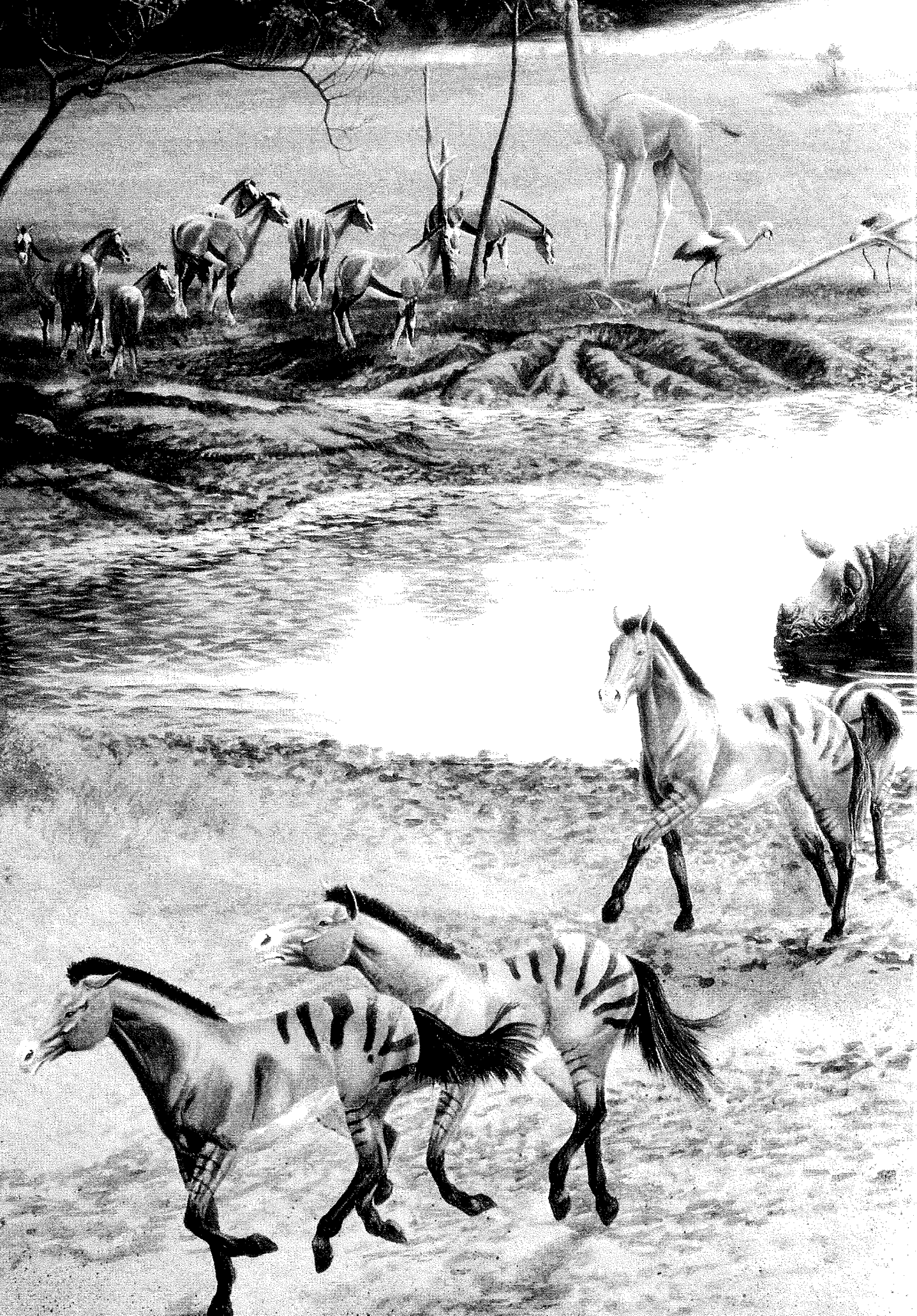
Cataloging Information:

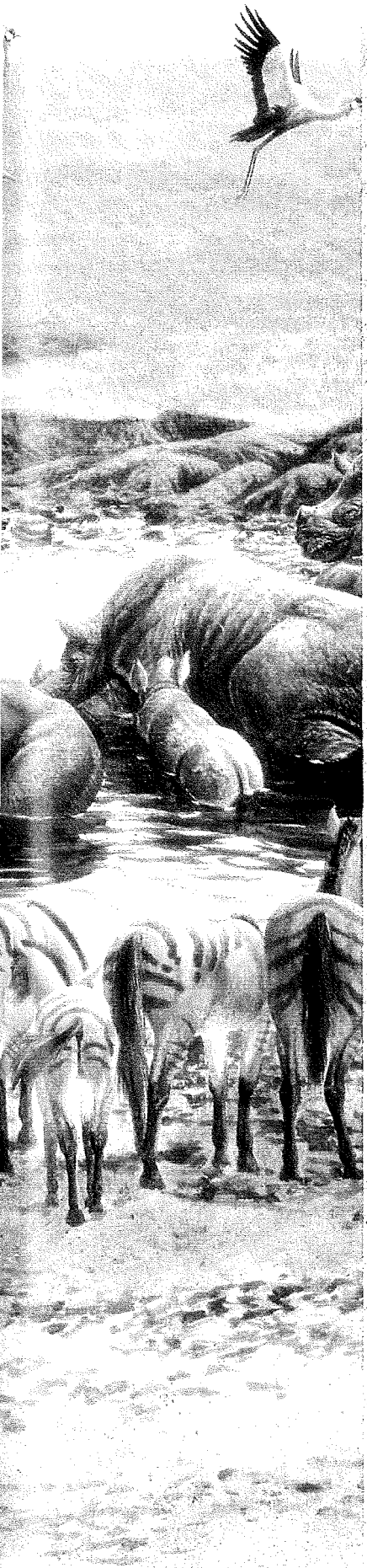
Geologic Time: Cenozoic Era (Age of Mammals), Eocene Epoch, Oligocene Epoch, Orellan Age, Whitneyan Age, Arikareean Age

Nebraska Paleontology Sites: Lewis and Clark Lake (Knox County), Chadron Formation, Toadstool Park (Dawes County), Brule Formation (Sioux County), Arikaree Formation (North Platte Valley)

Keywords: Hyracotherium ("dawn horse"), Titanothere ("thunder horse"), land turtles, *Palaeocastor* (beaver), *Stenomylus* (camel)

Photographs / Images: image of Titanotheres; badlands sabertooth (*Hoplophoneus*); skulls and cannon bones from camels; Henry Reider with Titanothere skeleton from the badlands of northwestern Nebraska (1931); Bruce Bailey treating a giant tortoise skeleton with preservative; varied fossils that might be found in a day of hunting in the badlands of northwestern Nebraska; *Palaeocaster* skeleton from Morrill County; *Mesocyon geringensis* from the Wildcat Hills; E H Barbour drawing of *Daimonelix* (devil's corkscrew) that he found near Harrison in 1891; spiral burrows of ancient beavers from Harrison Formation in northwestern Nebraska; adult and baby oreodont skeletons found in the Wildcat Hills





PART TWO

JUNGLES AND SAVANNAS

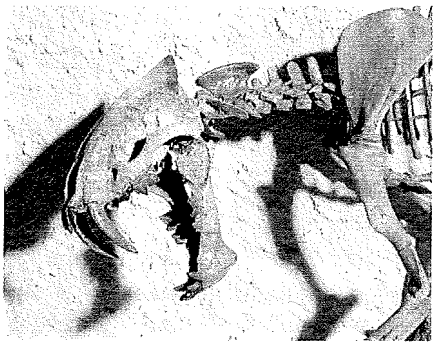
A gradually drying, frost-free climate characterized 30 million years of the Age of Mammals in Nebraska. Lush tropical forest was followed by savanna and then by grassland, and the fauna adapted. There were no grazing animals at the beginning of the period, yet they were dominant at the end.

Volcanic ash descends on a Miocene waterhole, now Ashfall State Historic Park.

CHAPTER THREE

Our Oldest Mammals

Tropical Forests and Volcanic Sandstorms



Badlands sabertooth *(Hoplophoneus)*

By Michael R. Voorhies
University of Nebraska State Museum

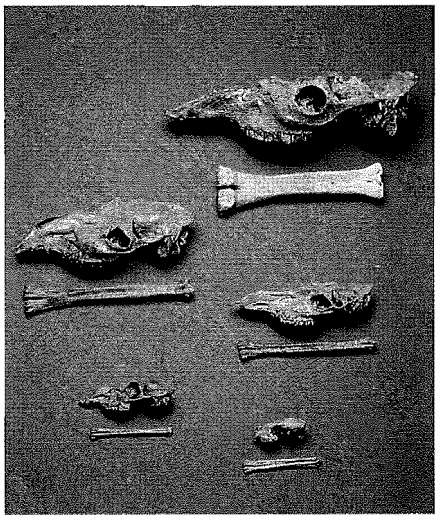
AS THE AGE OF REPTILES CAME TO A CLOSE and the last mosasaur carcass drifted ashore 65 million years ago, the sea drained away from the American heartland and never returned. Nebraska remained above sea level throughout the succeeding Age of Mammals (Cenozoic Era) but has continued to experience dramatic environmental changes, going from tropical forests to wooded grasslands then to glacial ice fields, shifting sand dunes and fertile prairies. All of those events and more are recorded in sedimentary layers, most of which were deposited by streams flowing eastward from the newly formed Rocky Mountains.

Eocene and Oligocene

We know that palm trees and crocodiles flourished in Wyoming between 50 million and 55 million years ago because their fossils and those of other tropical organisms are common in rocks of that age in basins between the mountain ranges. Our only direct evidence that this jungle habitat stretched east into what is now Nebraska is found in a thin layer of rusty-looking conglomerate perched high on a hill overlooking Lewis and Clark Lake in northern Knox County. This flint-hard deposit has grudgingly yielded a few teeth of characteristic early Eocene vertebrates, including crocodiles and, most significantly, the little cat-size "dawn horse" *Hyracotherium*. Fossils of that tiny hoofed mammal, the ancestor of all later horses, have been found at hundreds of locations in western North America and even in Europe, always in early Eocene deposits. Paleontologists have come to rely on *Hyracotherium* as an "index fossil" for the time period. It is one of several early Eocene index fossils found

Titanotheres lived in Nebraska until the end of the Eocene Epoch 34 million years ago.

at the Lewis and Clark site, which is the only known deposit of that age between the Rocky Mountains and the Gulf Coast. Others, if they ever existed, seem to have eroded away.

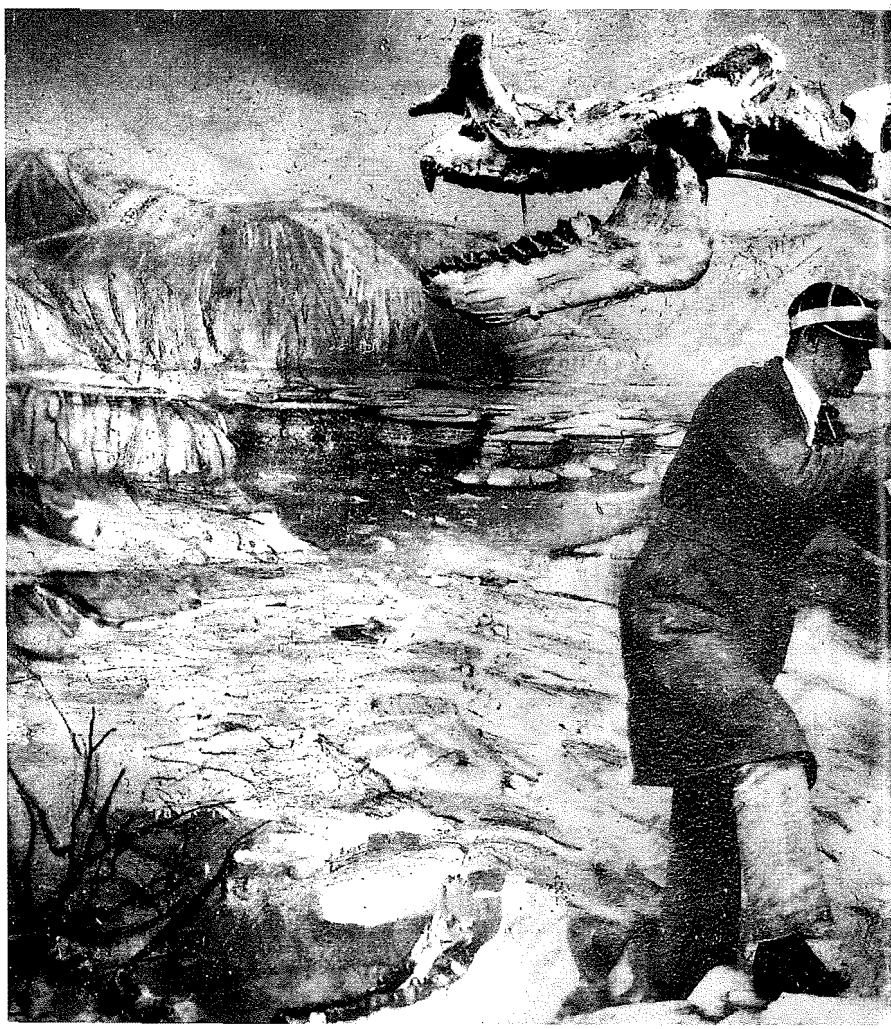


Camels lived in Nebraska for 35 million years. Skulls and cannon (foot) bones from five of the more than 50 species known are arranged here from oldest (bottom) to youngest. Smallest is an Oligocene specimen from the badlands. The next three, all Miocene, are from Agate, Hemingford and Valentine. The largest, a modern-size camel, is from Pleistocene deposits near Gordon.

Chadronian: 37 Million Years Ago

If Nebraska's fossil record is incomplete for the first 30 million years of the Age of Mammals, it becomes spectacularly good for the remainder of the era. A thick layer of multicolored mudstone and sandstone capped by a 34-million-year-old ash bed is the state's oldest deposit containing abundant fossil mammals. Called the Chadron Formation, the beds are exposed in the badlands carved by the White River and its tributaries in northwestern Nebraska and southwestern South Dakota. Microscopic study of the grains of rock making up the Chadron beds reveals that they originated in volcanoes far to the west and were carried out onto the plains by the wind or washed eastward by ash-choked rivers.

Early explorers noticed the abundance of vertebrate fossils in the badlands. By the 1840s, some stone bones had made their way east, and eager naturalists, including Joseph Leidy of Philadelphia, recognized them for what they were — relics of an ancient and strangely alien ecosystem. Leidy's beautifully illustrated descriptions of exotic skulls from Nebraska Territory stimulated further exploration of the badlands. During the next 150 years, many museums sent expeditions to the White River country where they found a bonanza of fossils.



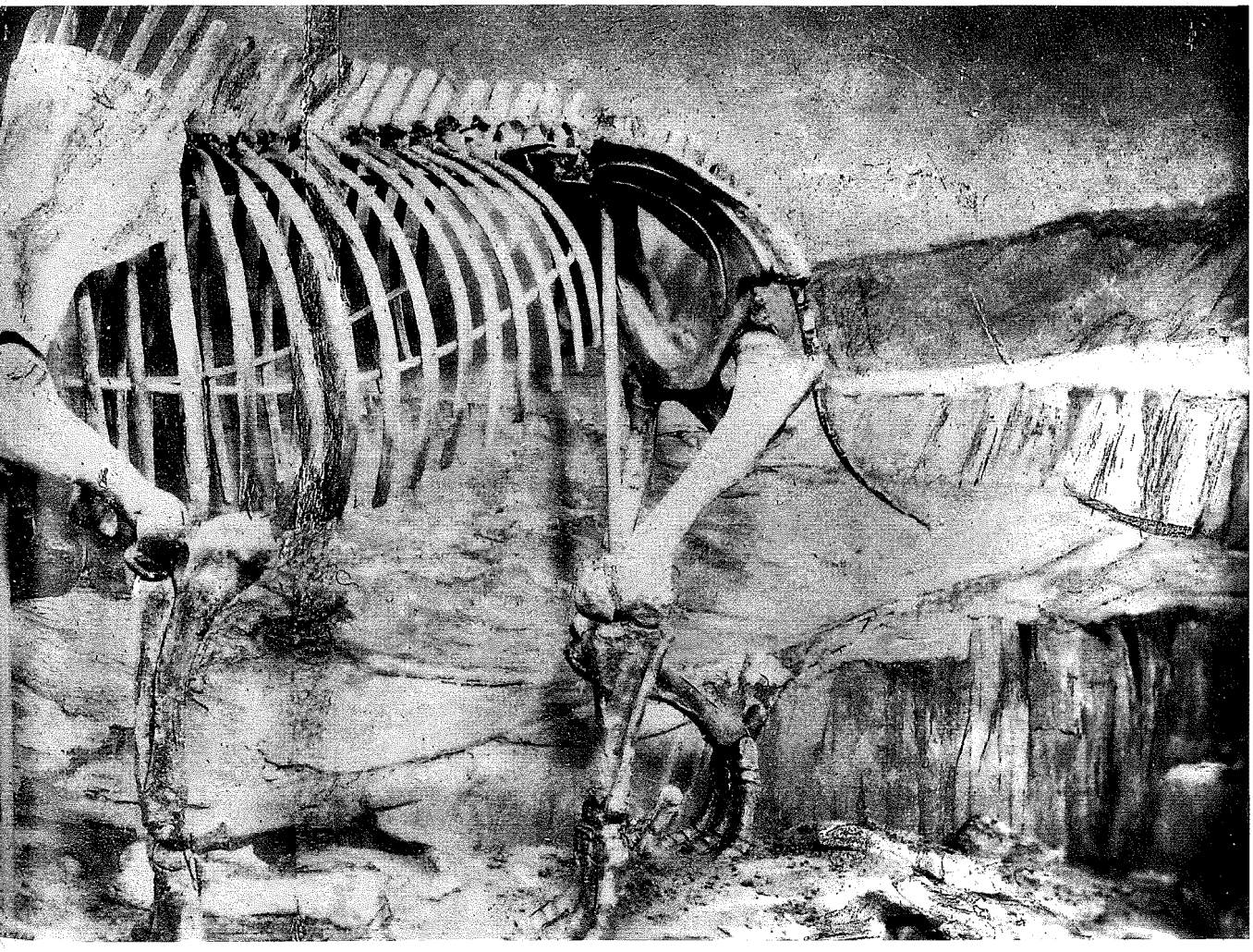
Startling new discoveries continue to be made in the Chadron Formation. Robert Emry, a native of Ainsworth who is now curator of vertebrate paleontology at the Smithsonian Institution, recently found the skeleton of a new species closely related to bizarre-looking mammals called pangolins or scaly anteaters that live today in tropical parts of Africa and Asia. Another Nebraskan, the late Gregg Ostrander, was prospecting for fossils north of Crawford when he discovered the richest known concentration of Chadron micromammals, including such creatures as primates, dermopterans ("flying lemurs") and mouse-size opossums, all exclusively tropical today. Along with the remains of alligators, aquatic turtles, boas and large armored lizards they suggest that the climate in the Nebraska Panhandle was warm and wet in the late Eocene.

The Thunder Horse

Titanotheres (the name means "titanic beast") are by far the largest of the extinct animals found in the badlands. Distant relatives of horses and other odd-toed hoofed mammals, those horned vegetarians were up to eight feet tall at the shoulder and may have weighed as much as 2.5 tons — almost as big as a circus elephant. Their bones were so abundant in some stream-channel deposits in the Chadron Formation that old-time fossil hunters spoke of "titanothere graveyards."

White explorers were not the first to notice the concentrations of petrified

Titanothere skeleton from Chadronian-age deposits in the badlands of northwestern Nebraska with Chief Preparator Henry Reider, who prepared it for display in 1931. "Thunder horses" were the largest Nebraska mammals before elephants arrived 20 million years later. Short-crowned molar teeth indicate that titanotheres ate soft, leafy vegetation.



ANCIENT CLIMATIC TRENDS

By Michael R. Voorhies, University of Nebraska State Museum

Fossils give us some of the most reliable clues about the severity of past climate changes and when they occurred. Because cold-blooded animals such as reptiles, amphibians and fish are especially sensitive to temperature fluctuations, their fossilized remains make excellent "paleo-thermometers."

Giant land turtles (tortoises) are a good example. Today those lumbering vegetarian tanks live only in the tropics — freezing or even near-freezing weather kills them in a matter of days. Tortoise shells nearly identical to modern ones are among the most common fossils found in Nebraska rocks dating between 37 million and 5 million years old (Eocene through Miocene). Most are a foot or two long, but occasional five-footers have been discovered. Paleontologists conclude from this nearly continuous record that Nebraska's climate was essentially frost-free before the Plio-Pleistocene Ice Age.

Remains of alligators are less common than giant land tortoises in Nebraska fossil beds, but several hundred well-preserved specimens have been found, including three new species from Miocene lake and stream deposits in the Niobrara River Valley.

Alligators require permanent water and warmth, so their fossil record traces precipitation as well as temperature. The last known Nebraska alligator died 9 million years ago and left its skeleton in a lake deposit that also preserved the remains of an extinct elephant called the scoop-tusker. The climate apparently became too dry for alligators on the plains long before it got too cold for them, judging from the fact that giant tortoises remained common for millions of years after the last Nebraska alligator died.

Coral snakes, boas, curl-tail lizards, alligator lizards, worm lizards and sirens are other warmth-loving species that today live much farther south, but have left their tell-tale bones in Nebraska's fossil beds. Detailed studies of the fossils by such scholars as J. Alan Holman of Michigan State University have shown that cold-blooded animals evolved much less rapidly than mammals.

During the time modern horses evolved from their three-toed ancestors, many reptiles and amphibians did not change at all — at least their skeletons did not. Such conservatism gives scientists added confidence in "lower" vertebrates as climate indicators although it obviously limits their usefulness in determining the age of fossil deposits.

With their insulating coats of fur or feathers, mammals and birds are generally more independent of temperature changes than are the reptiles and amphibians, so fossils of the warm-blooded animals usually make poor guides to ancient climates. The situation improves as we come closer to our own era. By about 500,000 years ago most modern species had evolved to their present form; presumably their climatic requirements have not changed radically since then.

The jewel-like fossil jaws of shrews and mice are especially useful in helping us decipher late Ice Age climates in Nebraska. Arctic shrews, spruce voles and collared lemmings are a few of the species that lived in Nebraska during times of maximum glaciation, but retreated north as the ice sheets receded. Fossil elephants and lions are spectacular and interesting, but they have much less to tell us about prehistoric climate than do their smaller cousins.

Highway Salvage Paleontologist Bruce Bailey treats a 10-million-year-old giant tortoise skeleton with preservative.

A day of fossil hunting in the badlands of northwestern Nebraska might produce (clockwise from lower left): rhino jaws, duck eggs, horse jaws, a camel jaw and skull, oreodont jaws, tiny deer jaw fragments and a land tortoise (center).

bones. The Lakota legend of the "thunder horse" is thought to be based at least partly on a tribal shaman's encounter with the gigantic horse-like skeleton of a badlands titanothere.

Most animals entombed in the Chadron mudstones are much smaller than titanotheres. One species of rhino approached the size of a small cow, but another (*Toxotherium*, the smallest known rhino) had a jaw only three inches long. Most of the dozens of other hoofed mammals are smaller than sheep. Horses, for example, averaged only 18 inches tall at the shoulder. Named *Mesohippus* (the "middle horse") the three-toed creatures were nevertheless much bigger than their early Eocene ancestors. A tiny cloven-hoofed mammal called *Leptomeryx* ("slender cud-chewer") far outnumbered horses in the Chadronian ecosystem, judging from the thousands of specimens found. It was a jackrabbit-size, deer-like creature with much longer hind legs than front legs, resembling in this and many other respects the mouse deer living in tropical forests today. A similar size ruminant called *Pseudoprotoceras* is much scarcer, but discoveries include the perfect skeleton of a pregnant female found by University of Nebraska State Museum paleontologist Lloyd Tanner and now on display in Morrill Hall. The list of animals goes on and on, and much of the fauna continues with only minor changes into the next mammal age.

Small World

As we climb upward through the badlands, at Toadstool Park for instance, we find our last titanothere bones just below a layer of white volcanic ash at the top of the Chadron Formation. Paleontologists recognize the highest occurrence of titanothere remains as the upper boundary of the Chadronian (late Eocene) mammal age.

Above the Chadron Formation are more layers of volcanic siltstone named the Orella (lower) and Whitney (upper) members of the Brule Formation. Like

Nebraska's oldest beavers were kitten-size creatures that dug burrows on dry land like prairie dogs. This *Palaeocaster* skeleton was collected from 29-million-year-old wind-blown volcanic sandstone in Morrill County.

the Chadron, they take their names from towns near the outcrops where they were first studied. The Orellan and Whitneyan mammal ages, dating from 34 million to 29 million years ago based on fossils found in the rock units, are recognized throughout North America. Collecting from these beds can be hazardous because they tend to erode into steeper slopes than the Chadron does. Many paleontologists have risked their own bones in an attempt to secure those of a long-lost species.

Whenever I sort through a collection of Oligocene fossils, I'm reminded of a passage in Mark Twain's book of western adventures, *Roughing It*, where Twain tells about napping under a sagebrush (the first he'd ever seen) in Nebraska and imagining that the world had suddenly shrunk around him. Gulliver-like, he fancied himself beneath the canopy of an ancient oak with birds (actually gnats) flitting among the branches and sheep (really ants) foraging around the trunk. That might be how most of us would feel if we were transported back in time 32 million years or so. Imagine horses and camels the size of foxes, deer that could stand in the palm of your hand and miniature hornless rhinos. But those aren't imaginary beings; unlike Twain's vision of a

dwarfed world conjured up out of thin air on a lazy afternoon, the badlands mini-kingdom existed in fact. The evidence, embedded in solid rock, is there for all to see.

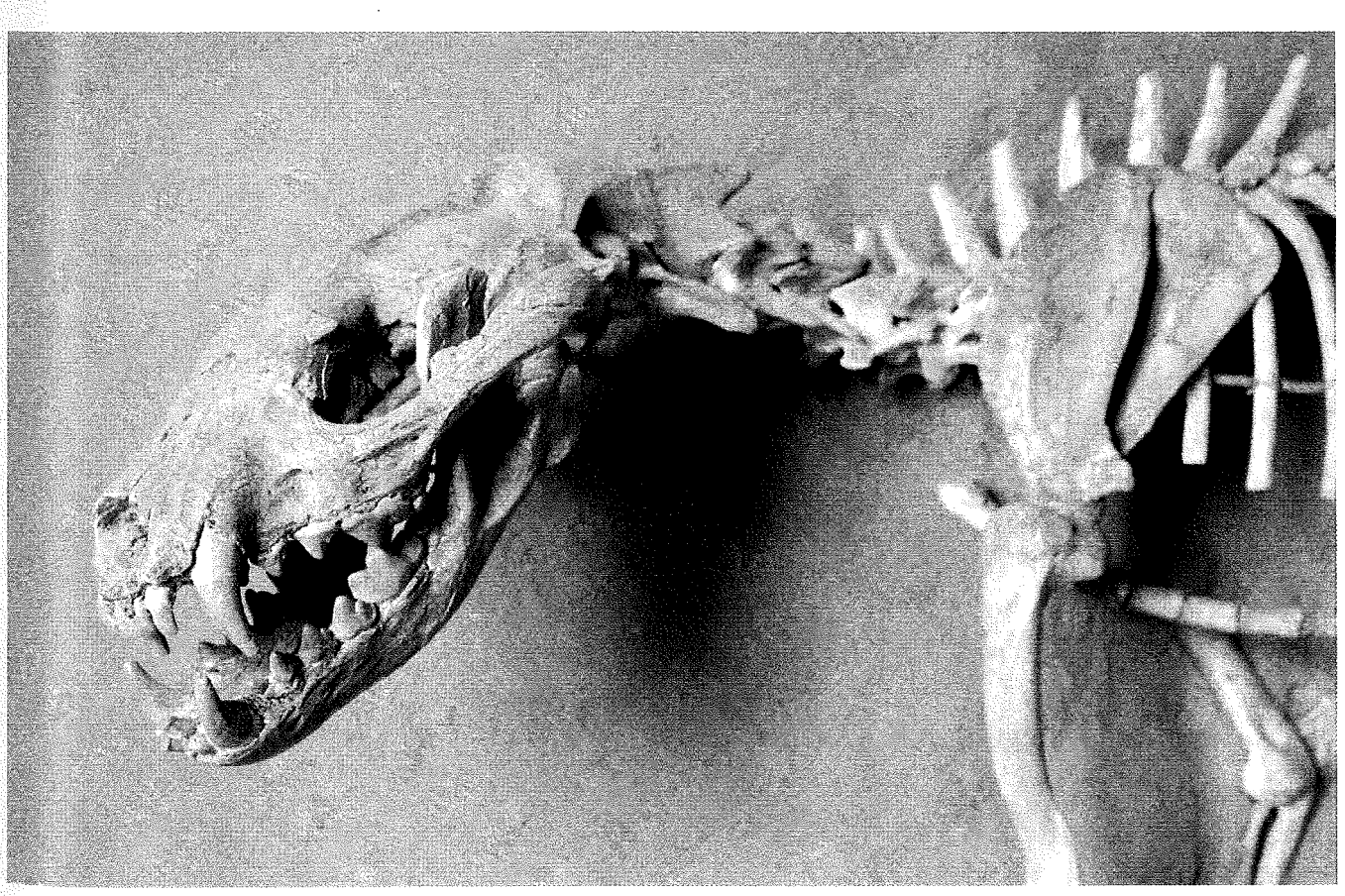
As might be expected, the miniature hayburners had small-scale predators to hunt them down. One was a long-fanged cat-like creature *Hoplophoneus* ("killing weapon") some species of which were only a foot high at the shoulder — pint-size versions of the fearsome monsters we will meet later. Primitive members of the dog family (*Hesperocyon* or "dog of the west") were not only small (six to eight inches tall) but were shaped less like a modern dog than like a mongoose, with short legs, a long body and an exceptionally long, heavy tail.

Probably the oddest-looking Oligocene carnivores to modern eyes would have been the hyaenodonts ("hyaena tooths") with their disproportionately long heads and a whole row of meat-slicing teeth in each jaw instead of just one as in modern predators. The largest species, *Hyaenodon horridus*, had a skull the size of a black bear's attached to its wolf-size skeleton. Other species were about the size of foxes and coyotes.

Many of today's small fry were even smaller 30 million years ago. The skulls of some species of rabbits *(Paleolagus)* are about the size of the last joint on your thumb, and you can hide the entire jawbone of a mini-possum (*Peratherium*) under a fingernail paring. Ancestral beaver skulls from the badlands are much smaller than those of muskrats today.

By keeping track of the exact level for each fossil found, paleontologists have discovered a pattern of gradual change through the nearly 8 million years it took for the rock layers of the badlands to accumulate. Some mammals, like titanotheres and primates, are found only in the Chadron, while others, including many kinds of camels, first appear at higher levels. Land turtles with

This nearly complete skeleton from 29-million-year-old Oligocene-age rocks in the Wildcat Hills was described as a new species of extinct dog, *Mesocyon geringensis*. It was about the size of a coyote but with a shorter snout, more massive teeth and shorter legs.



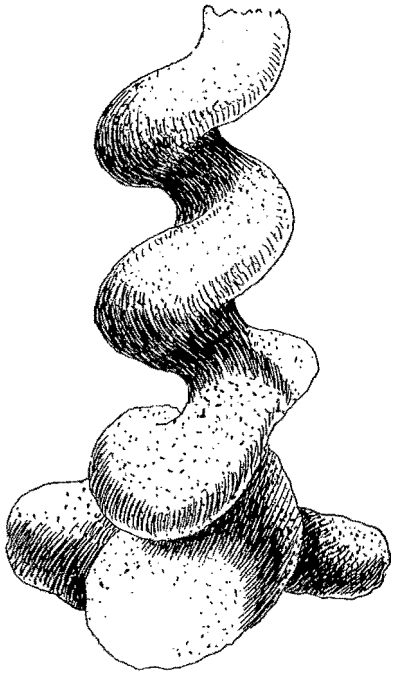
high-arched shells (tortoises) are common at all levels, but water-dwelling species, along with alligators, are found only in the Chadron and lowermost Orella. It appears the land was drying out — getting too dry for alligators but still warm enough for big land turtles. Drier conditions probably account for the disappearance of forest animals, such as primates and flying lemurs.

A Long Dry Spell

Stand anywhere in the badlands in northern Sioux County and look south. You'll see that the layers of banded mudstone that make up the badlands pass beneath a high wall of different-looking rock covered with pine trees. If you hike up into that formation, called the Pine Ridge, and look closely at the bedrock, you'll see that it is sandstone gritty enough to strike a match on and contrasting sharply with the clay-rich material of the badlands.

Geologists call the cliff-forming sandstone the Arikaree, named after a High Plains tribe, and have traced it throughout the Nebraska Panhandle and into Wyoming and South Dakota. In the North Platte Valley the steep upper ramparts of landmarks like Scotts Bluff, Chimney Rock and Courthouse Rock are Arikaree sandstone, volcanic in origin, while their gentler lower slopes consist of the finer-grained Whitney. Although stream-channel deposits do occur, much of the sediment fell directly from the air. The trend toward a drier climate that we saw in the badlands record seems to culminate in the Arikaree.

If you were an angler with a time machine, trying your luck at various times in the past, your poorest catches probably would have come in Arikareean times between 29 million and 19 million years ago. Paleontologists have found only a few scraps of fish, alligator and aquatic turtle bone in deposits of that age in Nebraska. Ten million years is a long time between bites, even for a determined angler.



E.H. Barbour drew this Devil's corkscrew *(Daimonelix)* near Harrison where he discovered the remarkable fossils in 1891. Skeletons of ancient gopher-like beavers are often found inside these structures, especially in "nest" chambers like the one seen here at the bottom of the spiral.

Spiral burrows of ancient beavers *(Palaeocastor)* continue to weather out of the early Miocene-age Harrison Formation in northwestern Nebraska. They are evidence that beavers of 24 million years ago lived in "towns" like prairie dogs do today.

Adult and baby oreodont skeletons displayed as found in Arikaree sandstone in the Wildcat Hills. Oreodonts, found in Oligocene- and Miocene-age rocks, have front teeth specialized for browsing, not grazing. Their bodies were long and heavy with limbs built for strength and flexibility rather than speed.

Arikareean: 29 Million Years Ago

Abundant tortoises, lizards and boas, along with a rich diversity of insect-eating mammals such as hedgehogs, moles, shrews and mini-possums indicate that warm temperatures prevailed during Arikareean times. Among plant-eating mammals we see a definite trend toward development of tall-crowned teeth, an adaptation for chewing tough, fibrous food containing a lot of grit. Graceful little camels called *Stenomylus* illustrate this trend. In 1907, an entire herd of the three-foot-tall camels was discovered near Agate south of Harrison in Sioux County.

Three years earlier, one of the most important fossil sites in North America was discovered at Agate, a great bonebed containing thousands of bones of rhinos and chalicotheres, huge horse-like animals with claws rather than hooves. Major excavations by the Carnegie Museum, Yale University, Amherst College and the American Museum in New York as well as the University of Nebraska were carried out on the two Agate hills between 1904 and 1923. The site became a national monument in 1965. My colleague, Bob Hunt, recently explored the Agate bonebed in detail and determined that it originated from a catastrophic drought during which large herds of the small rhinos, *Menoceras,* perished along with smaller numbers of chalicotheres and enormous hoofed scavengers called entelodonts.

Hunt and his crew also made an exciting discovery on a hill above the great waterhole at Agate: a series beardog skeletons buried in their own dens. Those extinct, wolf-like animals were the largest predators of their day.