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Article Summary: Southeastern Nebraska's rock outcrops reveal an alternation of land and sea in the Paleozoic Era. They contain fossil skeletons deposited when an inland sea occupied the area. Compressed remains of trees and plants in occasional seams of coal provide evidence that at other times the land emerged above sea level.

Cataloging Information:

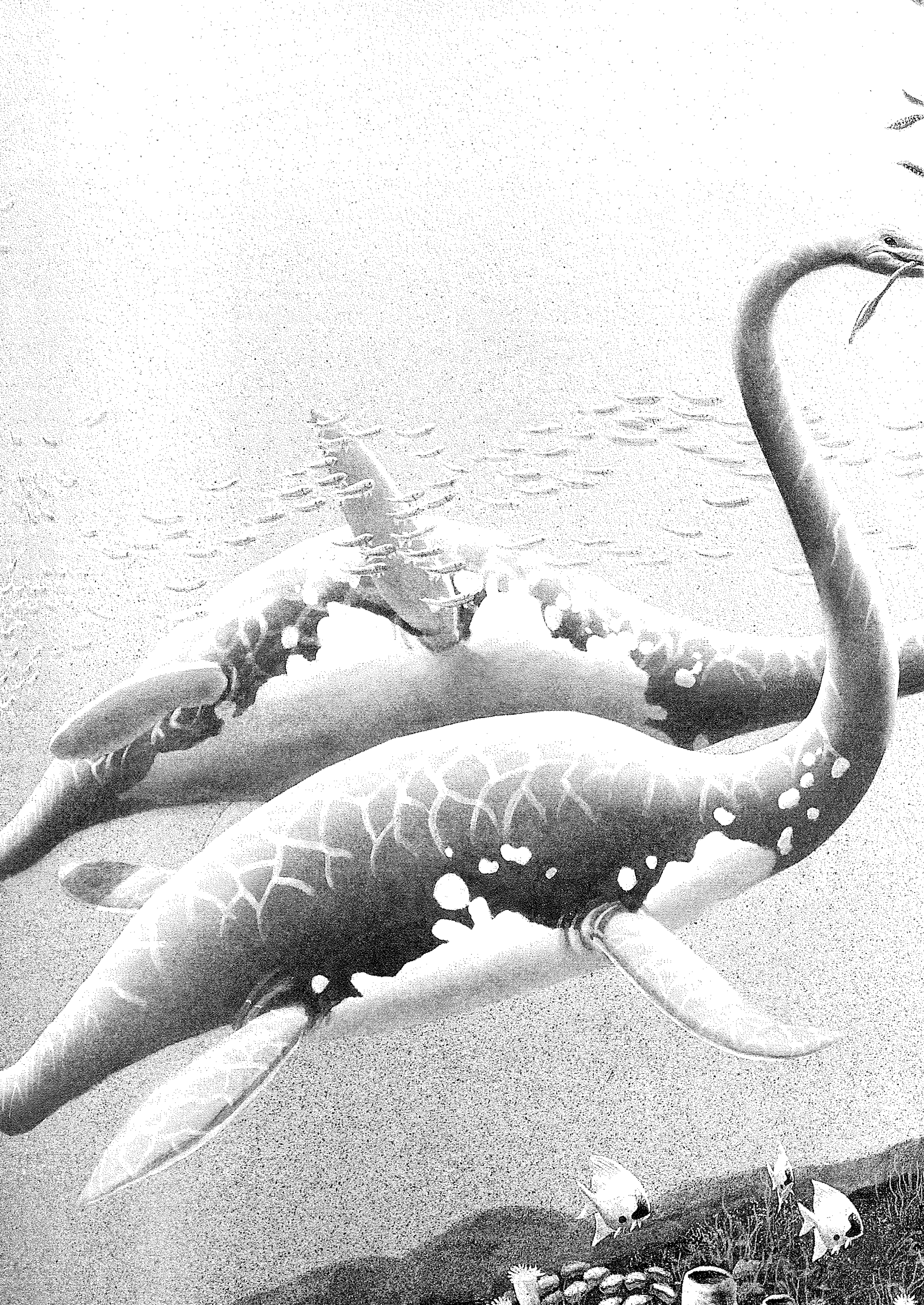
Names: Loren Eiseley, W D "Ted" White

Geologic Time: Paleozoic Era (the time of ancient life), Pennsylvanian Age, Permian Period

Nebraska Paleontology Sites: Wildcat Ridge, Nemaha River, Platte River, Louisville and Plattsmouth (Cass County), Indian Cave (Richardson County)

Keywords: crinoids ("sea lilies"), fusulines, bryozoans ("lace animals"), brachiopods ("lamp shells"), sea urchins, trilobites, nautiloids, ammonoids, paleoniscoids, *Iniopterygia* ("nape fin"), eurypterids ("well-developed paddles")

Photographs / Images: image of plesiosaurs and sharks cruising Nebraska's ancient sea; image of a trilobite and arthropods swimming near a cluster of corals; trilobite fossil; image of crinoids; crinoid cup and stem segments; southeastern Nebraska rock outcrops; drawing of fusulines, marine fossils the size and shape of grains of rice; teeth of Nebraska's oldest sharks; brachiopods common in Southeast Nebraska limestone and shale beds; horn corals found in Cass County



PART ONE

THE ANCIENT SEAS

Fossils of saltwater creatures in limestone and shale beds of eastern Nebraska tell us that for hundreds of millions of years the region was covered by a great inland sea. The waters occasionally retreated, allowing land plants and animals to enter, but the sea prevailed.

Plesiosaurs and sharks cruised Nebraska's ancient sea.

CHAPTER ONE

Shark-infested Coral Seas

Shifting Coastlines 300 Million Years Ago

Trilobite fossil

By Michael R. Voorhies, Curator of Vertebrate Paleontology
University of Nebraska State Museum

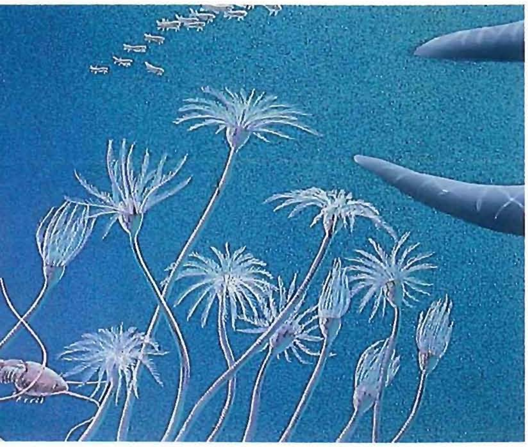
LAND AND SEA BATTLED FOR SUPREMACY across the American mid-continent as the Paleozoic Era, the time of ancient life, drew to a close. The oldest rock outcrops in Nebraska, in the southeastern one-sixth of the state, bear witness to this titanic struggle. In rock bluffs along the Missouri River and tributaries such as the Nemaha and Platte rivers, in road cuts and rock quarries, you can see thin, horizontal layers of limestone and shale alternating in a more-or-less regular fashion with beds of sandstone and occasional thin seams of coal.

Because the limestone and limy shale beds are crowded with fossil skeletons of animals that live today only in saltwater, geologists conclude that the beds were formed when an inland sea occupied the area. Coal, on the other hand, is made from the compressed remains of trees and other land plants, so beds containing coal are interpreted as evidence for times when the land emerged above sea level.

The shoreline shifted back and forth at least a dozen times across terrain so flat that a sea level rise or fall of only a few feet would inundate or drain hundreds of square miles. The reason for those periodic ups and downs is puzzling, but since they occurred at the same time that glacial ice caps were alternately growing and melting in the Southern Hemisphere, most researchers believe that global climatic cycles were responsible.

A trilobite and arthropods swim near a cluster of corals in Nebraska's Paleozoic sea.

Crinoids, or "sea lilies," lived in the equatorial sea covering southeastern Nebraska 300 million years ago.



Astride the Equator

Although distant glaciers might have controlled sea level in Nebraska, a tropical climate prevailed locally. Studies of magnetic minerals preserved in Pennsylvanian and Permian age rocks show that North America was much farther south then, placing Nebraska and Kansas astride the equator, so it should come as no surprise that fossilized creatures commonly found in limestones of that age in southeastern Nebraska resemble denizens of today's warm tropical seas. If we were able to put on scuba gear and dive into the sea 300 million years ago near, let's say, Weeping Water, what would we have seen?

Corals, probably brightly colored, would catch our eye. Solitary species nicknamed "horn corals" and more sociable species that built colonial skeletons would be common where the water was clear and the bottom firm enough to offer secure attachment. Living corals feed on tiny animals the corals capture with their fleshy tentacles. They grow best in shallow, sunlit waters, as do sponges, another group of marine organisms represented by abundant fossils in Nebraska's Permo-Pennsylvanian rocks. Muddy water clogs their filter-feeding mechanisms, so sponge fossils are evidence that underwater visibility would have been good on our imaginary dive.

Lily Gardens in the Sea

Spectacular gardens of crinoids growing from the bottom on long, waving stalks would have covered many acres of the sea floor. Sometimes called "sea lilies," crinoids are actually animals that filter microscopic food from water currents passing through their elaborate plumbing systems. Sections of crinoid stems are among the most common fossils found in southeastern Nebraska. Countless grade-schoolers have been charmed by picking up these little jointed cylinders from the crushed limestone of a playground or parking lot. The stems are like stacks of small crystalline coins, each one perforated with five holes, an arrangement betraying their kinship to starfish and other echinoderms.

Much scarcer as a fossil is the business end of the crinoid — the cup

Crinoid cup and stem segments from Pennsylvanian-age deposits, the oldest exposed in Nebraska.

In southeastern Nebraska rock outcrops, thin layers of 300-million-year-old limestone and shale alternating with beds of sandstone and occasional seams of coal preserve a record of changing levels of Nebraska's ancient sea.

with its halo of jointed tentacles perched at the end of the stem. Fossil crinoid specialists, including Professor Roger Pabian of the University of Nebraska, have identified hundreds of crinoid species on the basis of well-preserved crinoid cups collected in Nebraska and adjacent states.

Microscopic Marvels

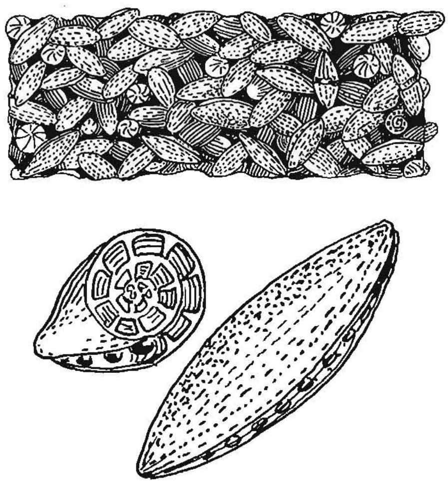
Other creatures likely to show up in limestone are objects about the size and shape of grains of rice. These are fusulines, single-celled creatures that secreted porous, limy skeletons as they grew. Entire limestone beds in parts of Nebraska and Kansas are made of them; they must have lived there by the trillions when the chemistry and temperature of our seawater suited them.

With a low-power magnifier you can see that these little grains actually look like tightly coiled jellyrolls, and with a microscope you can learn why paleontologists get so excited about these insignificant-seeming specks of rock. Each fusuline is an architectural marvel; the spacing of the pillars and the arrangement of their minute pores are mathematically precise and uniform within a population. But when we compare samples collected from successive limestone beds, we find striking changes. Each time the sea retreated and came back, the fusulines had a slightly different shape — an example of gradual evolutionary change.

Such accurately measurable changes are attributes of a good clock, and fusulines have therefore been heavily used by geologists in dating and correlating rocks across North America and even around the world in Russia where paleontologists have found the same sequences of fusuline shapes in their limestone beds.

Studies like this are not merely of academic interest. Vast amounts of oil, gas, salt and other valuable commodities occur in Permo-Pennsylvanian rocks of the midcontinent. Finding and tracing those deposits involves teamwork by many scientists, including paleontologists skilled in reading the time signatures of extinct creatures such as fusulines.

As long as our eyes are adjusted for seeing small things, we should at least glance at another kind of miniature life form growing on the sea floor. Looking like perforated twigs are bryozoans, or "lace animals," with skeletons so delicate that rough water would destroy them. A diver would find thickets of them only in quiet, sheltered water, probably far from shore.



Fusulines, marine fossils the size and shape of grains of rice, form beds of "rice rock" in southeastern Nebraska. Samples from successive limestone beds exhibit striking differences, an example of gradual evolutionary change that helps geologists date and correlate rocks.

Ancient Shellfish

Both near shore and offshore would be a great diversity of clams and snails, some attached to the sea floor, some meandering across the surface, still others burrowing deep in the sediment. Only a specialist would detect much difference between the 300-million-year-old mollusks and modern seashells, but even a casual observer might notice that those living closer to shore have thicker shells, on the average, than those in deeper, quieter water. That difference, probably related to wave resistance, is well known to marine biologists but has only recently been used to pinpoint water depths in Nebraska's ancient seas.

Ranking next in abundance after crinoids in fossil collections from Nebraska's most ancient rocks are brachiopods or "lamp shells" (one species resembles Aladdin's lamp). Like clams, they have hinged shells, but in brachiopods the two parts of the shell are of unequal size and shape while in clams they are mirror images.

Brachiopods are filter feeders that live attached to the sea floor by a short, flexible stalk. They are rare animals in modern oceans but were among the most successful shellfish in Paleozoic seas. Many species apparently thrived in muddy environments since we often find hordes of their shells in shale beds originally laid down as deposits of silt and clay. One species is especially interesting to Nebraskans because of its name, *Juresania nebrascensis*, and because it belongs to a bizarre group, the spiny brachiopods, which evolved long slender spines, presumably to prevent them from settling into the mud. They must have looked like small, immobile porcupines sitting on the sea floor.

An observant diver would notice other spiny creatures — the sea urchins — scuttling around on the tips of their moveable spines. Broken parts of those armored scavengers are common fossils in some shale and limestone beds.

Trilobites are another animal we could glimpse scooting across the sea floor. Those segmented creatures might remind a Nebraska gardener of a pill bug, but they were strictly marine animals that breathed by means of gills. Trilobite fossils have a certain bug-eyed elegance and are much sought after by collectors; unfortunately they are rare in Nebraska. By the time our Pennsylvanian sediments were deposited, trilobites were already well on their way to extinction, an event that finally happened at the end of the Permian.

Marine Predators

With all this seafood spread out on the sea floor like a high-priced smorgasbord, where were the predators? The fossil record shows a rich assortment of highly mobile killers, some with backbones and some without.

Chief among the invertebrate carnivores were related to today's chambered nautilus. Called nautiloids and ammonoids, those jet-propelled, large-eyed animals resembled squid except for having heavy external shells, coiled in some species, straight in others. Like submarines, they could control their buoyancy by pumping water in or out of the hollow chambers of their shells. Although some earlier Paleozoic nautiloids were more than 15 feet long, the ones found in Nebraska are far smaller and would have posed no threat to our imaginary diver. Not so the sharks, some of which were well over 15 feet long and armed with razor-sharp teeth.

Sharks were at the top of the marine food chain and top predators tend to be rare, both in the modern world and in the fossil record, but sharks are exceptions to the rule. You have a good chance of finding shark fossils in almost any marine sediments younger than 400 million years because sharks continuously shed old teeth and grow new ones, producing as many as several thousand potential fossils in a lifetime. Based on tooth shape, dozens of different kinds

of sharks have been recognized in Nebraska's Pennsylvanian and Permian fossil beds.

Slender, sharp-pointed teeth clearly belonged to sharks that ate fish or other slippery, fast-moving prey. Other shark teeth, including some huge ones up to four inches across and an inch thick, are blunt and show lots of wear, suggesting they were used for crushing hard-shelled invertebrates like clams or brachiopods. Some blocks of limestone from commercial rock quarries, at Louisville for example, are a hash of broken invertebrate shells along with a few discarded shark teeth. Such hashes probably were produced by the feeding of "clam-crusher" sharks.

In most modern sharks the teeth are the only parts hard enough to be fossilized in ordinary environments, but many of the species that swam Nebraska's Paleozoic seas also had sharp, serrated spines at the leading edges of their fins. Rare specimens up to two feet long show that some of these spine-bearing sharks were enormous.

Hard parts such as teeth and spines may give us an idea of how big the ancient sharks were and even some idea of what they ate, but because their skeletons were made of soft, edible cartilage we could usually only guess what the entire animals looked like — until the shale-splitters went into action, that is. A group of fossil hunters, most of them amateurs, have revolutionized our understanding of shark evolution by patiently splitting thin beds of black shale in which cartilage and other perishable materials are well preserved. Those carbon-rich layers, exposed by limestone quarrying near Plattsmouth and at other locations in southeastern Nebraska, have produced the compressed bodies of sharks and other soft-bodied animals such as jellyfish and shrimp-like crustaceans.

One of the most adept practitioners of the art of finding such prizes and getting them out of the rock undamaged is W.D. "Ted" White of Omaha. White, a retired electrician, not only developed a sharp eye for fossils but also

Nebraska's oldest sharks include both fish-eating and shellfish-crunching varieties. Blunt teeth of the giant clam-crushing shark, *Agassizodus*, upper right, suggest they crushed hard-shelled invertebrates. Slender, sharp-pointed teeth of the cladodonts indicate a diet of fish or other slippery, fast-moving prey.

developed special tools and techniques for dealing with intractable slabs of shale that tend to break in every direction except the one you want them to. His skill and patience were rewarded with a collection that would be the envy of many professional paleontologists, not only because of the exceptional completeness and rarity of many specimens but because he kept accurate records of exactly where each one came from. Many of White's fossils are in major museum collections, and he has had new species named after him.

One of the perfectly preserved sharks found and collected by White is the centerpiece of a new display on Nebraska sharks in the Toren Gallery of Ancient Life in Morrill Hall on the University of Nebraska campus. The torpedo-shaped fossil is mounted with its belly toward the viewer. With fins flaring out behind the head and crescentic rows of teeth marking the position of the underslung jaws, it seems to be cruising overhead. Details of the soft anatomy, including muscles and stomach contents, are replicated by phosphatic minerals in that amazing specimen. The reason for such exquisite preservation of parts that normally don't fossilize seems to be that the black shales were originally deposited on stagnant, poisonous areas of the sea floor, probably in fairly deep water. Without oxygen, the normal scavengers could not live, so carcasses that fell to the bottom remained intact instead of being consumed and scattered as they would be in a normal marine environment.

Fish: The Ordinary and the Bizarre

When we count up the fossils, sharks are clearly in the lead as the most abundant predators in Nebraska's Paleozoic seas, but Ted White and other collectors have also found examples of fish called paleoniscoids, a primitive group having skeletons made of true bone rather than cartilage as in the sharks. An armor coat of small, diamond-shaped scales helped to protect them from shark attack, but telltale fossils show that the strategy didn't always work — some are bitten cleanly in two and others seem to have been mangled, partly

Brachiopods, or "lamp shells," are common in the limestone and shale beds of southeastern Nebraska. Like clams, they have hinged shells, but the two parts are of different size and shape.

swallowed and then spit out. Some slabs of shale are so covered with fish parts it looks as if someone forgot to hose out the fish house after cleaning bluegills.

Among the most attractive of the paleoniscoids, in fact, are deep-bodied little fellows quite reminiscent of today's sunfish although only distantly related to them. From their body shape and fin placement we can conclude that they were good at hovering and darting but could not compete with sharks at high-speed cruising.

Probably the weirdest animals discovered by White and his colleagues in the shale-splitting battalion are some unsharklike cartilage fish so different from any other living or extinct group that an entirely new order of fishes had to be named by the specialists who studied them. The name *Iniopterygia* means "nape fin" and refers to the huge pectoral fins that stick out behind the head at the top of the body, just where the nape of the neck would be if they had one. They may have used their monstrous pectoral fins to "fly" through the water the way present-day sea turtles do, using their front flippers. Certainly the tiny, weak tail of those aberrant fish could not have been used for swimming, and it appears their pelvic fins were adapted to another function entirely — reproduction. As in many sharks, the pelvic fins of some individual iniops (presumably males) are stiffened by rods of cartilage into so-called claspers used in mating. The claspers of some specimens are equipped with hook-like objects shaped like little hands.

An educated guess about the relationships of the iniops is that they may be remotely related to distant cousins of the sharks called chimaeras of today's oceans, but the fact is that they remain a total mystery.

In 1986, the Paleontological Society presented Ted White with the Harrell Strimple Award, an honor given annually to an amateur paleontologist who has made outstanding contributions to our understanding of life on earth. White certainly belongs in that elite category.

Unlike most modern corals, horn corals were solitary and did not form reefs. These fossils were found in Cass County.

Coal Swamps: Life above Sea Level

Plant remains are best preserved in coal beds and in freshwater shale beds associated with them. Nebraska currently has no commercial coal mines, but small "pick-and-shovel" operations such as the Honey Creek Mine in Nemaha County operated briefly early in the 20th century. Fragments of leaves, stems and roots of ancient plants related to ferns, liverworts and horsetail rushes occur in and near the coal seams, conjuring up visions of vast lowland swamps. Occasional fossil insects hint at the diversity of invertebrate life that flourished in the coal swamps.

Teeth and bones of a variety of freshwater fish and small amphibians have been collected from stream deposits such as the Indian Cave Sandstone. Some of the most unusual freshwater predators found in the Nebraska fossil record are scorpion-like arthropods called eurypterids ("well-developed paddles") believed by some scientists to have competed with early fishes for food.

New sites in Richardson County promise to add many concrete details to our currently hazy notion of life above sea level during the Permian. Crews from the University of Nebraska have recently collected complete skeletons of lungfish and eel-shaped amphibians preserved in fossil burrows. Modern lungfish live in tropical lakes and rivers subject to seasonal drought. Since they have lungs as well as gills, they can survive for months in mud-lined burrows that they excavate whenever their habitat dries up. The newly collected fossils suggest that some ancient residents of southeastern Nebraska mudflats were using the same trick 280 million years ago. Paleontologist Matthew Joeckel has analyzed associated siltstone beds and determined that they were deposited by wind, good evidence that intense arid episodes occurred.