PHOTOS BOTH PAGES BY CHUCK GREINER

Thick, heavy scales characterize a primitive fish fossil, found in shale by Page County coal miners. From Pennsylvanian period, some 300 million years ago.

Tiny, chainlike edges distinguish *Halysites catenulatus*, a fossil coral found in eastern Iowa. From Silurian period (400 million years ago).

Underwater Iowa—where graceful crinoids once swayed in ancient seas

By Ginalie Swaim

Fossil photography by Chuck Greiner

Research by William M. Johnson

Cluster of starfish, found near Le Grand. From Mississippian period, 335 million years ago. Entire limestone slab (about 3'x5') has 183 starfish and other species.

IMAGINE LIFTING AWAY the layers of Iowa soil down to bedrock, to rock layers that formed during mind-boggling measurements of time—epochs and periods and eras, with rich names like Pennsylvanian, Mississippian, Devonian, Silurian.

Imagine going so far back in time that the area we know today as Iowa was much closer to the equator and was covered with warm, shallow seas.

The effort is numbing. We look out the window at fields and highways and think: Tropical seas? Over Iowa? Give us proof.

The proof is in geology, of course. Experts can read time in the layers and grains of rock. Although they are alert to subtle changes in color, texture, and composition, geologists (like us) also appreciate the more obvious clues from the past—fossils.

The fossils on these two pages were all found in Iowa and represent the Paleozoic era of 225 to 570 million years ago, during which fishes, amphibians, then finally reptiles and insects appeared. Mosses, horsetails, and ferns developed. The fossils here range from coral from the Silurian period (roughly 400 million years ago), to a primitive fish from the Pennsylvanian period (a mere 300 million years ago).

Some of Iowa's most remarkable fossils, recognized internationally, are those of a class of marine animals called crinoids. These fossils, 335 million years old, are featured at the State Historical Building in Des Moines in a new museum exhibit, "Flowers of the Iowa Seas." The exhibit reveals the flower-like beauty of fossilized crinoids, the intricacy of working with them, and the passion of some Iowans who devoted lifetimes to their study.

Preserved in Iowa limestone for 335 million years or more, crinoid fossils are rock-solid evidence that their habitat—our Iowa—was once a warm, shallow sea. All that is missing is to imagine the crinoids underwater, alive with color and movement.

Two crinoid fossils look like pressed flowers on limestone. These marine animals were abundant during the Paleozoic era, 225 to 570 million years ago.

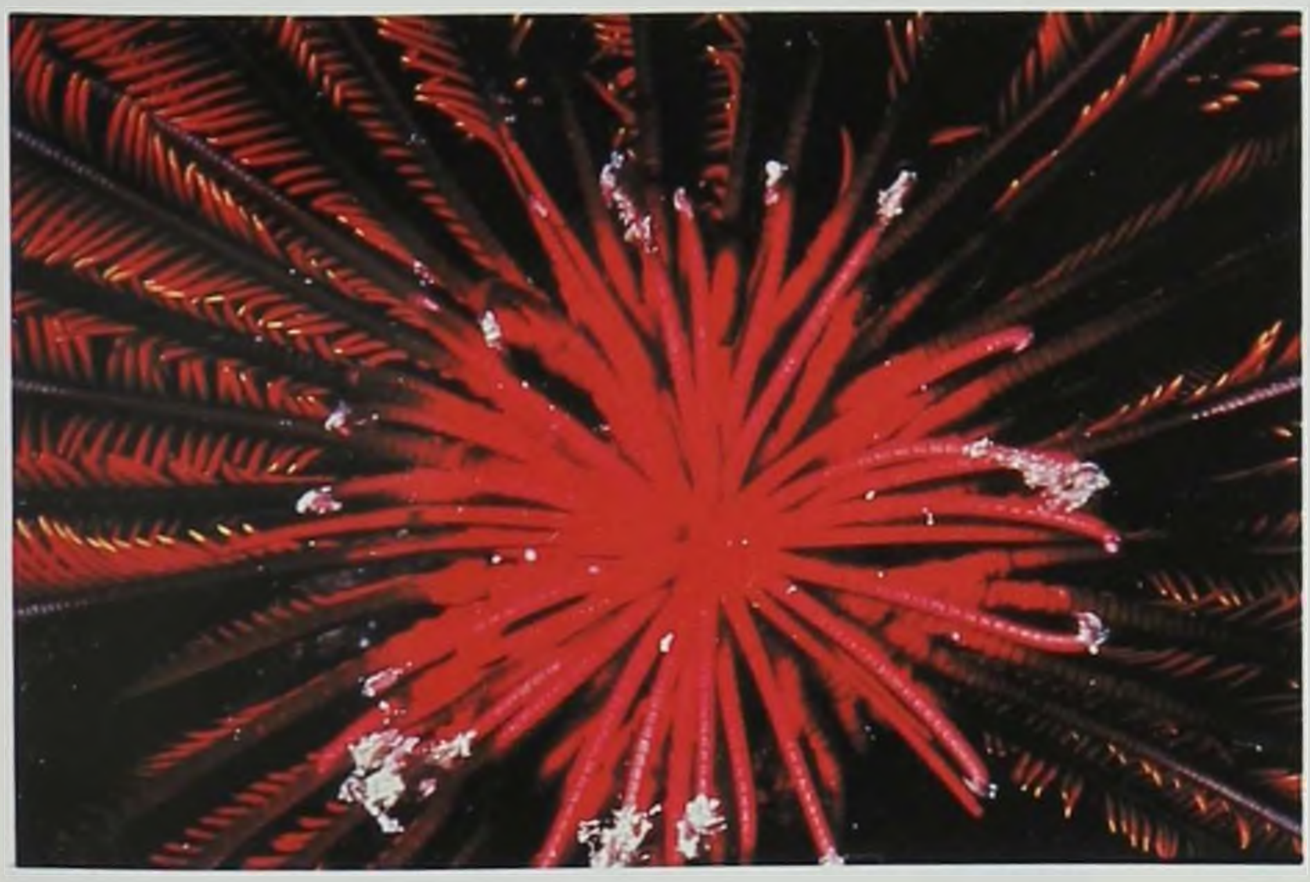
FOR COLOR AND MOVEMENT, we turn to modern crinoids. Photographed in the Bahamas and other shallow, tropical oceans (environments probably similar to Iowa's ancient marine seas), these crinoids are a few of about 600 species found today. (The kind that most resemble Iowa's prehistoric crinoids now live in cold, deep oceans instead of warm, shallow seas.)

Although their beauty has earned them the popular name of "feather stars" or "sea lilies," crinoids are not plants. Close relatives of starfish, sea urchins, sand dollars, and sea cucumbers, crinoids are echinoderms, animals without backbones. Most attach to objects or to the sea floor. Some, like the ones on these pages, are stalkless. Others, like most of the ones from Iowa's ancient seas, have long, jointed stalks, perhaps stretching up to fifty feet in length. The stalk supports the animal's crown (the cup-like calyx and arms) into the currents to feed on plankton.

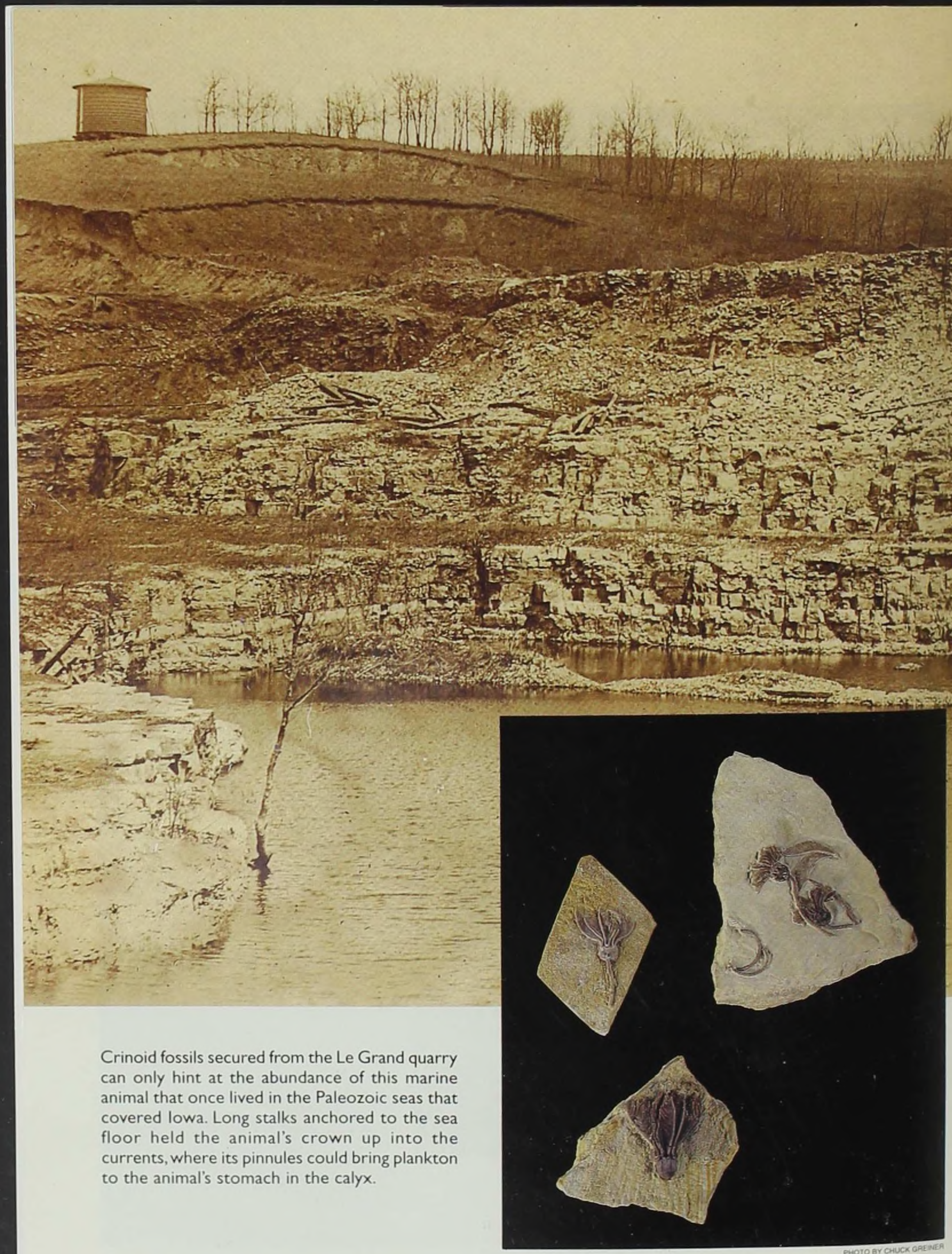
University of Iowa geologist Brian Glenister, who has studied living Pacific Ocean crinoids, emphasizes the fragile nature of a crinoid's body. "Within a few hours of death of a modern crinoid, it will fall to pieces," he explains. "The ligaments that hold together the skeletal plates will break down. If you take a living crinoid out of the water and place it on a flat surface, it will soon break itself into pieces, slowly writhing."

It seems a miracle, then, that any remnants of a crinoid's delicate structure could remain together long enough to become fossilized, that something so fragile as a crinoid could be preserved in stone for hundreds of millions of years. The key to preservation must lie in rapid burial, commonly in a flow of lime mud and sand, before the bonding ligaments decay.

PHOTOS BOTH PAGES BY DONALD B. MACURDA, JR.



Brilliantly colored, shallow-water living crinoids lack stalks but, like Iowa's ancient crinoids, have millions of food-gathering pinnules on their graceful "arms." Donald B. Macurda, Jr. photographed these crinoids at depths of twenty-five to seventy-five feet on coral reefs at locations cited. Top left: Note tiny, hair-like pinnules on *Nemaster rubiginosa* (Jamaica). Top right: *Comanthina schlegeli* uses some of its arm to cling to rocks (Australia). Bottom right: Bright red *Himerometra robustipinna* is one of the larger crinoids (Australia). Bottom left: *Capillaster multiradiatus* fans out its arms to filter the passing currents (Israel).

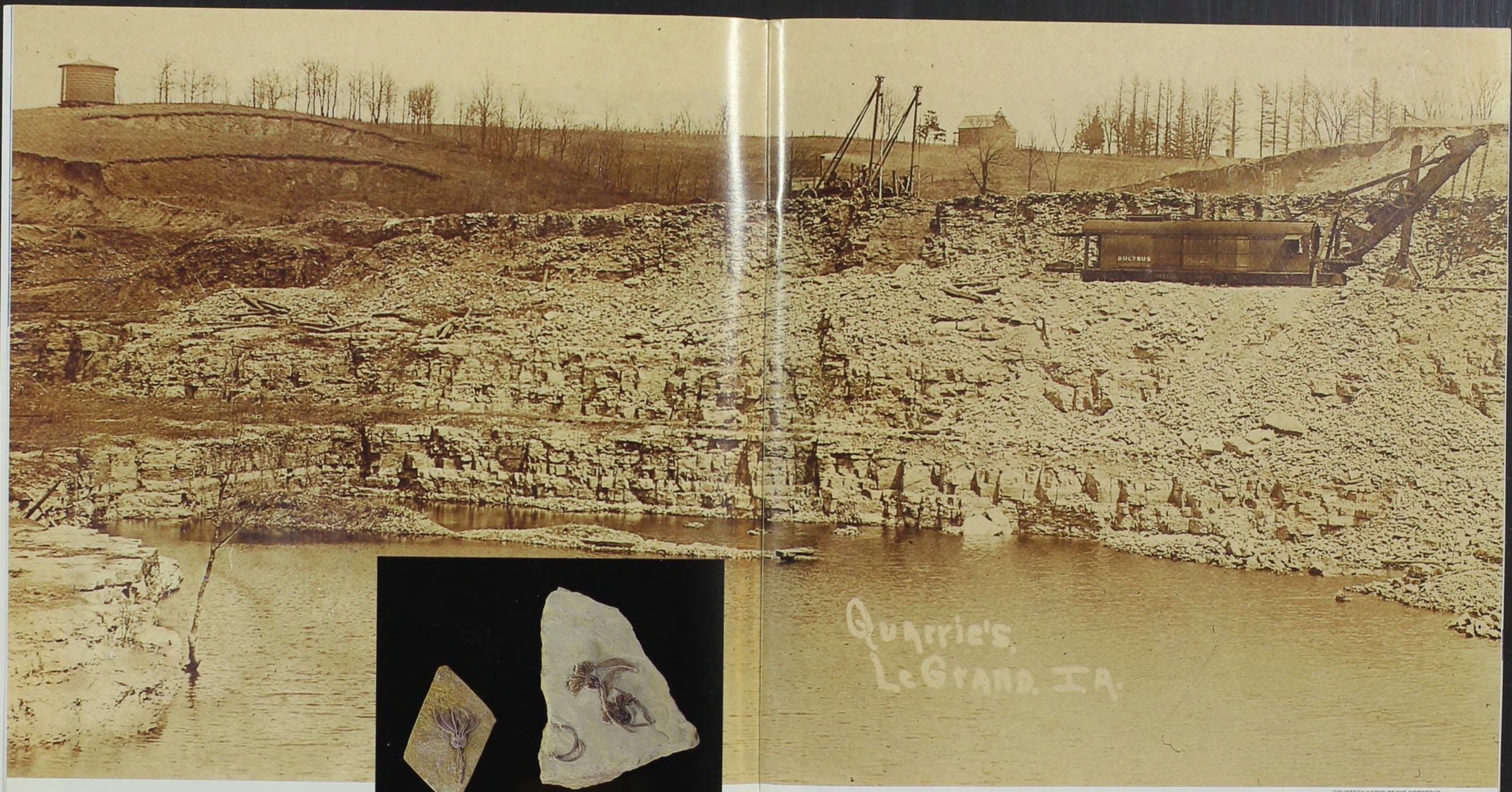


Crinoid fossils secured from the Le Grand quarry can only hint at the abundance of this marine animal that once lived in the Paleozoic seas that covered Iowa. Long stalks anchored to the sea floor held the animal's crown up into the currents, where its pinnules could bring plankton to the animal's stomach in the calyx.

PHOTO BY CHUCK GREINER

COURTESY KAREN BEANE NORSTRUD

ONLY A FEW PLACES in the world—especially sites in Indiana, Montana, and Germany—have yielded ancient crinoids as well preserved as those from the Le Grand quarry in Marshall County, Iowa. Quarried since the 1860s, the limestone has been used as ballast in railroad beds, for agricultural lime, and as road gravel. Some layers of limestone, better suited for building and carving, were quarried by Italian stone cutters from Chicago; in fact, the Old Historical Building in Des Moines was built of Le Grand limestone. But the Le Grand limestone that has been most treasured is not that which housed history, but that which represented history itself—the thousands of crinoid fossils found there between the mid-nineteenth and mid-twentieth centuries.



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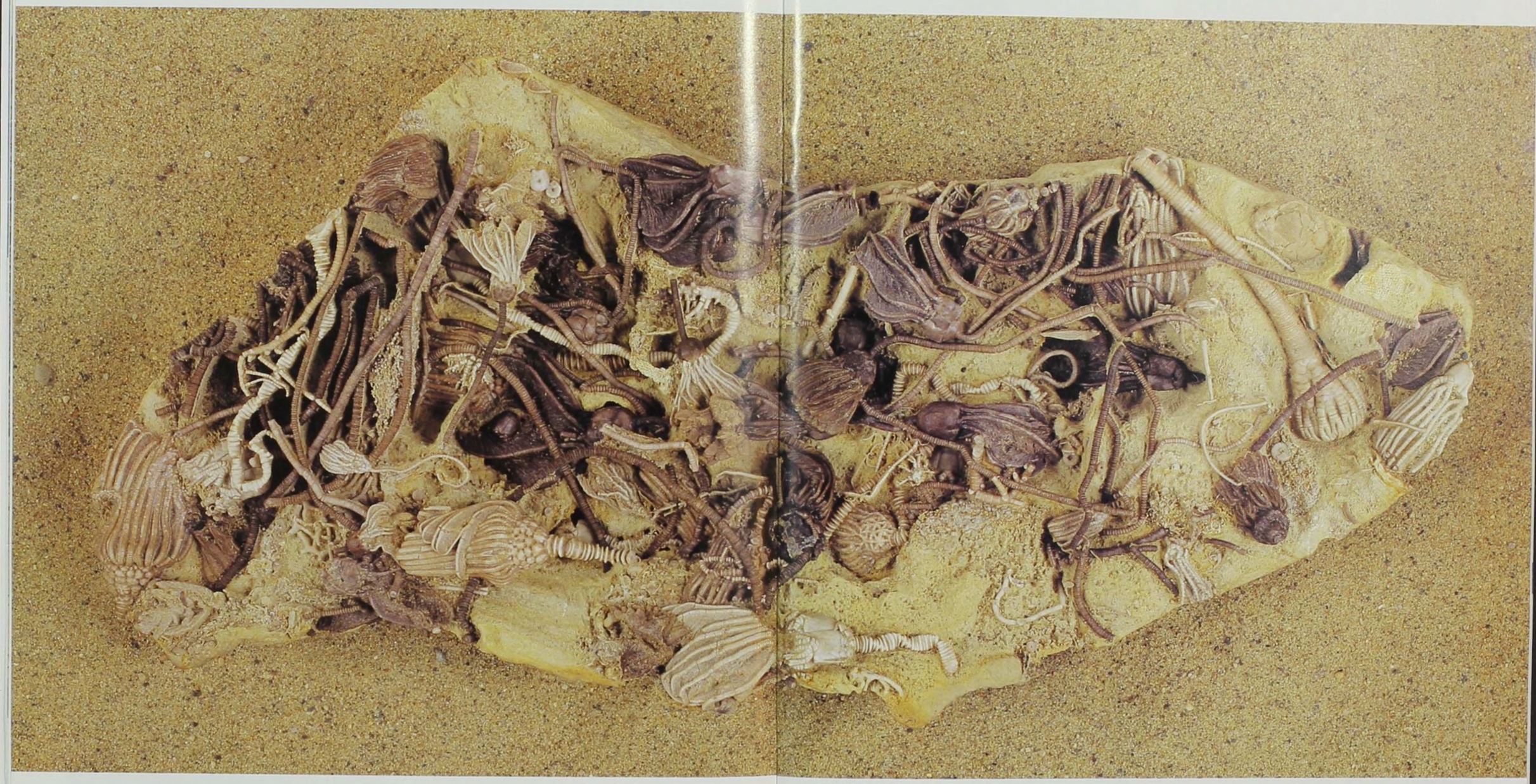
Opposite: Workers at the Le Grand quarry. Above: Gritty beauty of fossilized crinoids. Even though crinoids are animals, the fossils are sometimes called "sea lilies"; the word "crinoid" comes from the Greek *krinon*, meaning "lily." (For close-up of this specimen, see front cover.)

DESPITE THE DYNAMITE and rock crushers used at the Le Grand quarry, many slabs of limestone with fossil crinoids were salvaged. In 1874 the first "nest" (or accumulation) of crinoids was found, indicating a shallow depression in the sea floor where the bodies of dead crinoids had collected. Quarry operators learned to watch for clues—sometimes no more than a cross-section of a stalk—to such deposits. The quarry attracted paleontologists throughout much of the nineteenth century and into the next.

LE GRAND CRINOID FOSSILS are phenomenal because they are so complete. Experts believe that the dead crinoids drifted into a shallow depression in the sea floor and were quickly buried by fine-grained lime mud. Over time, the mud turned to limestone. As the crinoids turned into fossils, the stalk, the calyx, the petal-like arms, the feathery pinnules—all remained intact, despite their own fragile nature, the roughness of water currents, and the weight of sediment that buried them.

PHOTO BY CHUCK GREINER

Crinoid fossils lie in a tangle, exactly as the dead marine animals were buried millions of years ago. Note the jointed, button-like stalks, the plates on the cup-like calyx, and the petal-like arms. In the 1970s museum curator Richard Boyt prepared this slab, carefully clearing away the surrounding limestone. He even removed the limestone under portions of the stalks, so that the stalks bridge over open space.



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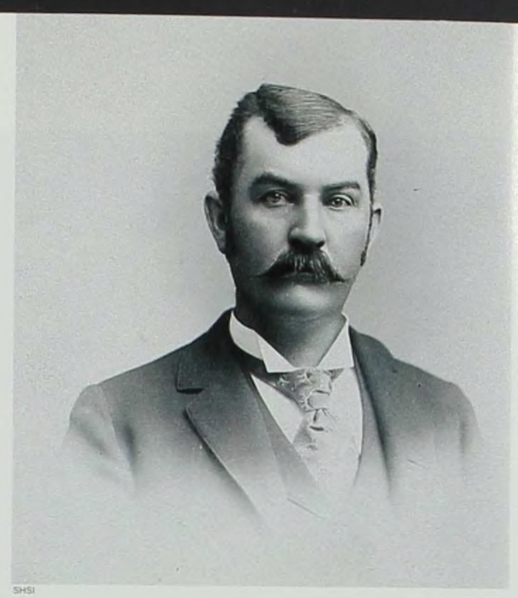

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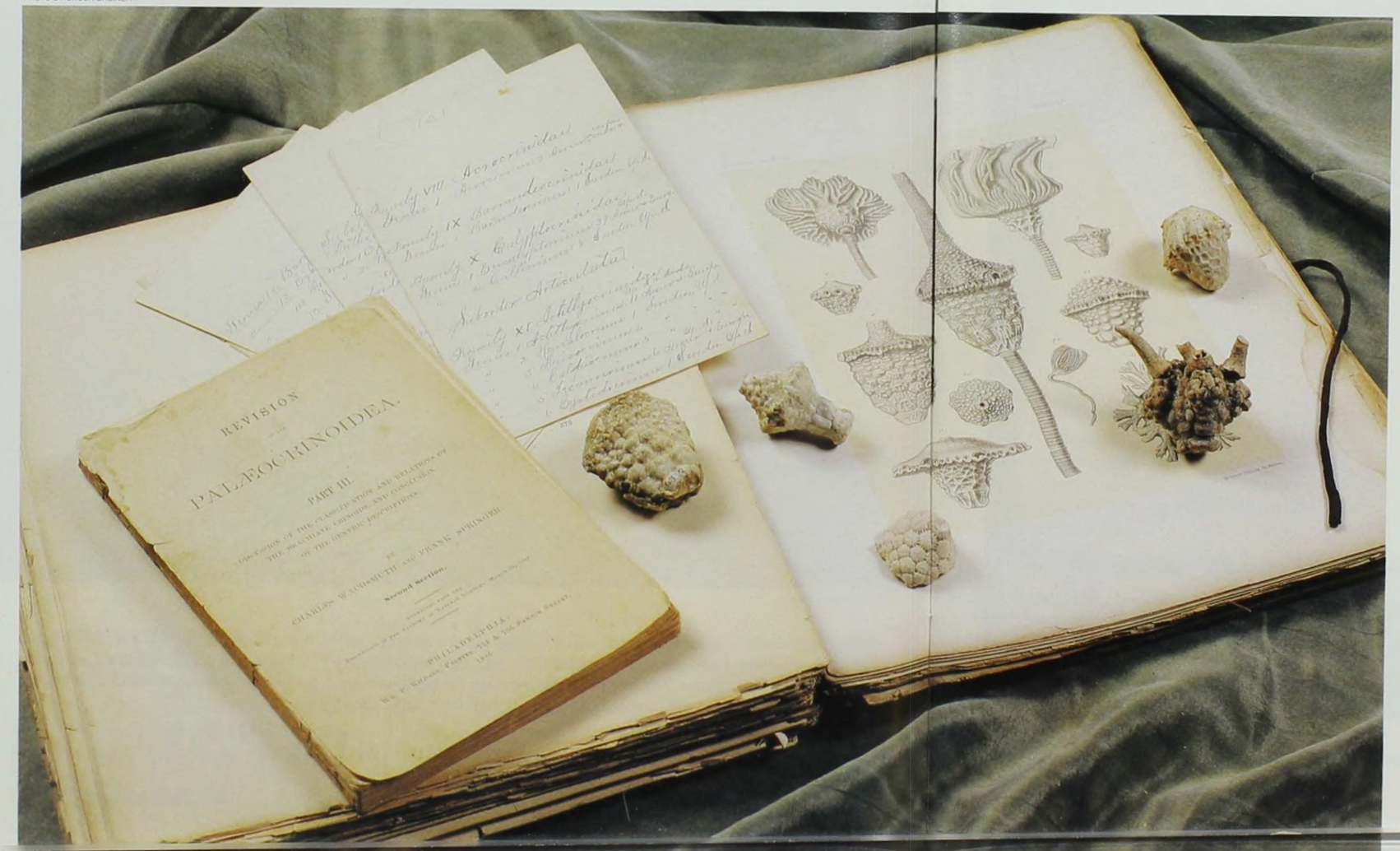

WHAT IS IT ABOUT CRINOIDS that they become the passion of amateur and professional geologists alike? Is it the wonder that these animals once swayed in the ancient tropical seas that covered Iowa? Is it the fragile beauty of a crinoid embedded in gritty limestone? Is it the good fortune of finding a fossil complete with stalk, calyx, and arms?

Whatever it is that attracts individuals to crinoid fossils, Iowa has had its share of self-trained amateurs who have contributed significantly to the science of paleontology. Years before the great crinoid finds at Le Grand, German emigrant Charles Wachsmuth (far left) moved to Burlington, Iowa, and started a grocery. Plagued by ill health, he sought exercise by exploring the nearby limestone cliffs, and collecting and studying the portions of fossilized crinoids he found there. As his collection and knowledge grew, so did his reputation. In 1873 renowned geologist Louis Agassiz hired him to study crinoids at the Museum of Comparative Zoology at Harvard University. Wachsmuth's wife, Berhardine, often joined in his collecting, researching, and writing.

Another Iowan, Frank Springer (near left), was a law student at the University of Iowa when he became interested in paleontology after hearing Agassiz lecture in Iowa City. Springer established a law practice in Burlington, and later New Mexico, but his real passion was fossils, and he often joined Wachsmuth in collecting.

The crinoids Wachsmuth and Springer found in the Burlington area were mainly nut-size balls (only the calyx of the crinoid) that weathered out of the limestone bluffs. Combining these with crinoid fossils found elsewhere, they diligently studied the crowns, distinguishing the species by the number and arrangements of plates on the calyx. (Living crinoids secrete calcite plates to provide support and protection for their soft tissues.) Wachsmuth and Springer collaborated on several publications, including the massive volume titled *North American Crinoidea Camerata*, which expanded and refined the identification and systemization of many species.

Like many geologists, professional or self-trained, Wachsmuth and Springer visited the Le Grand quarry. There they encountered a young farm boy named Burnice H. Beane. Talking with experts fueled Beane's passion for crinoids. He would bring amateur crinoid collecting into the next century.

Opposite: Above from left, Charles Wachsmuth and Frank Springer. Below: Burlington crinoid fossils rest on the pages of Wachsmuth and Springer's *North American Crinoidea Camerata* (1897), and across from another of their collaborative publications and B. H. Beane's handwritten field notes.

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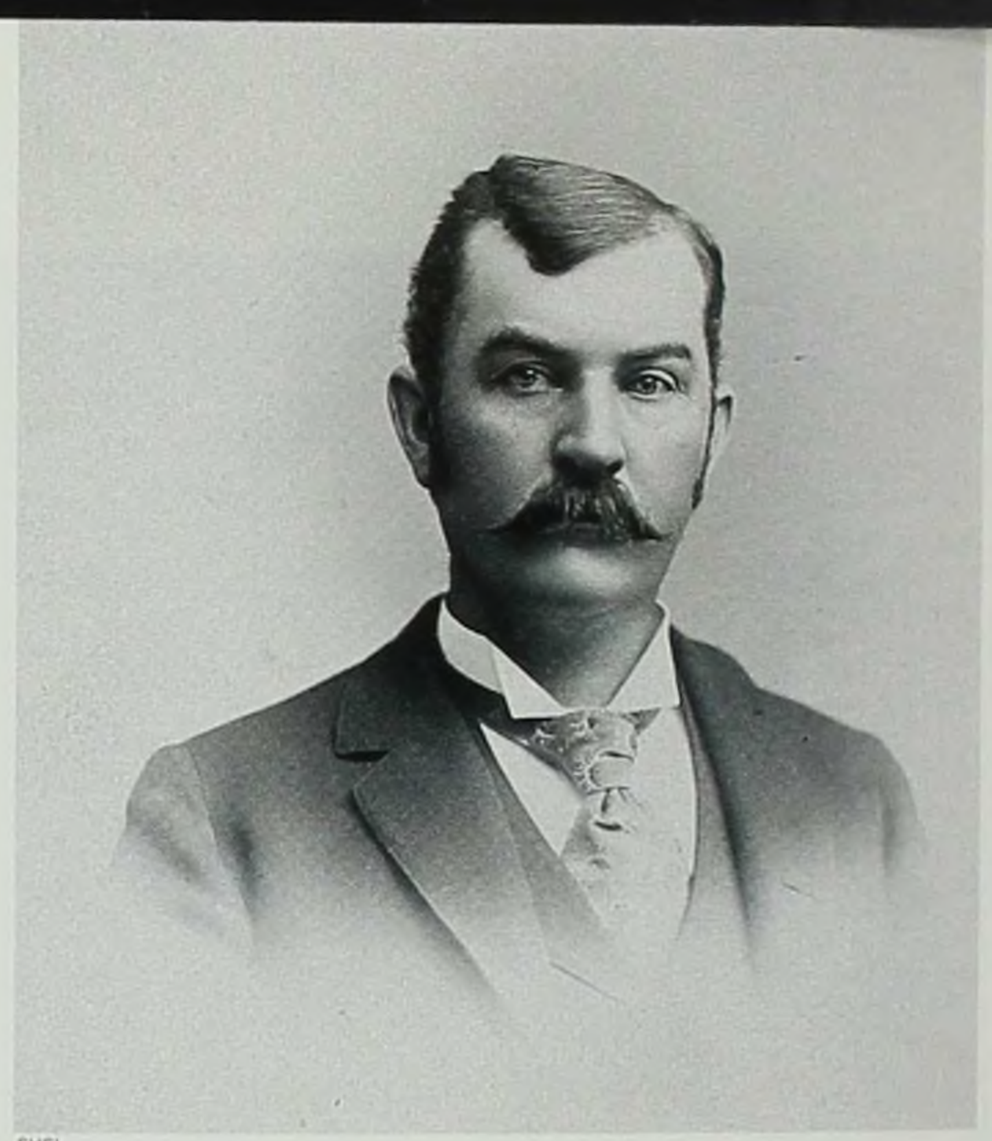

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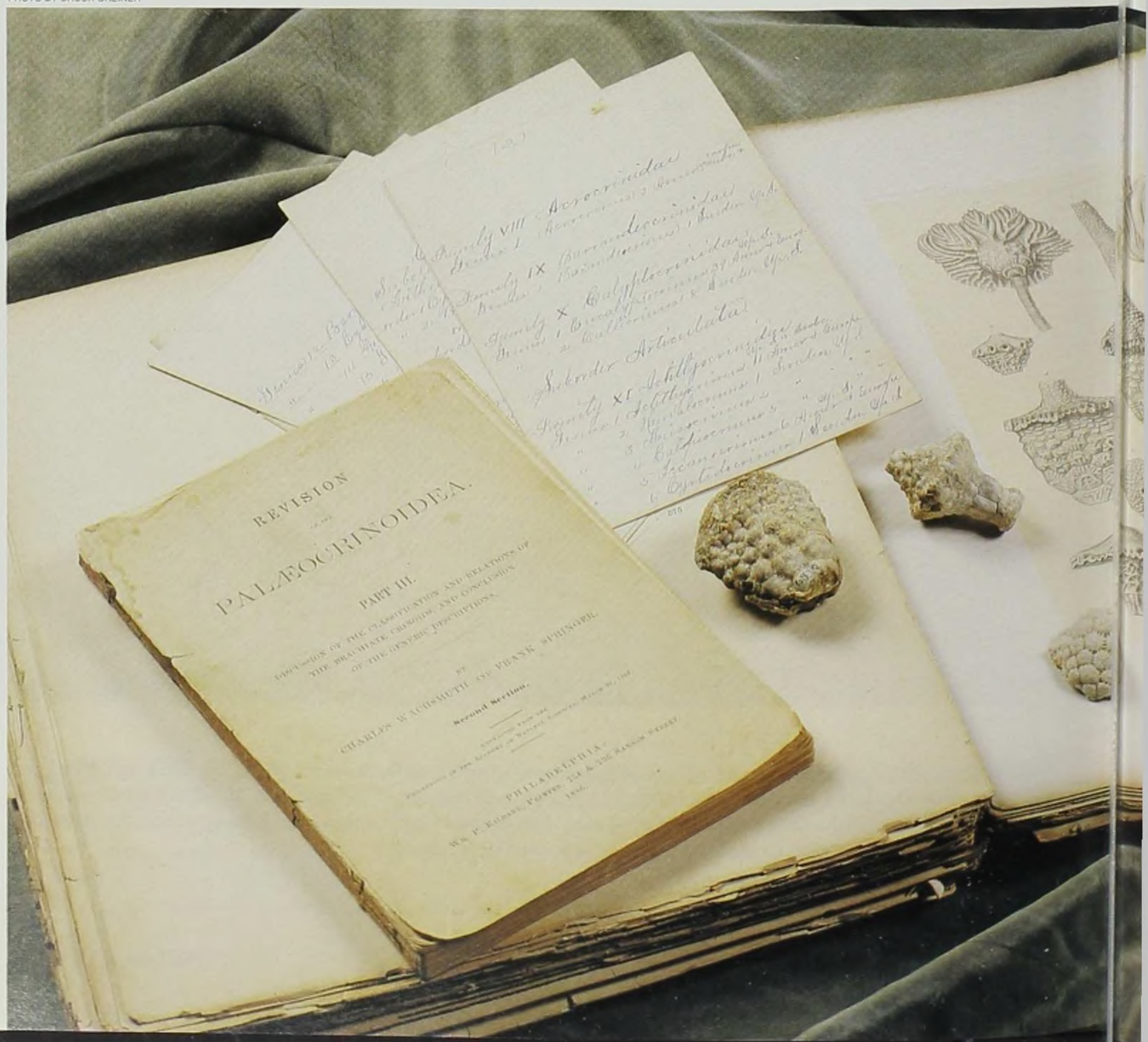

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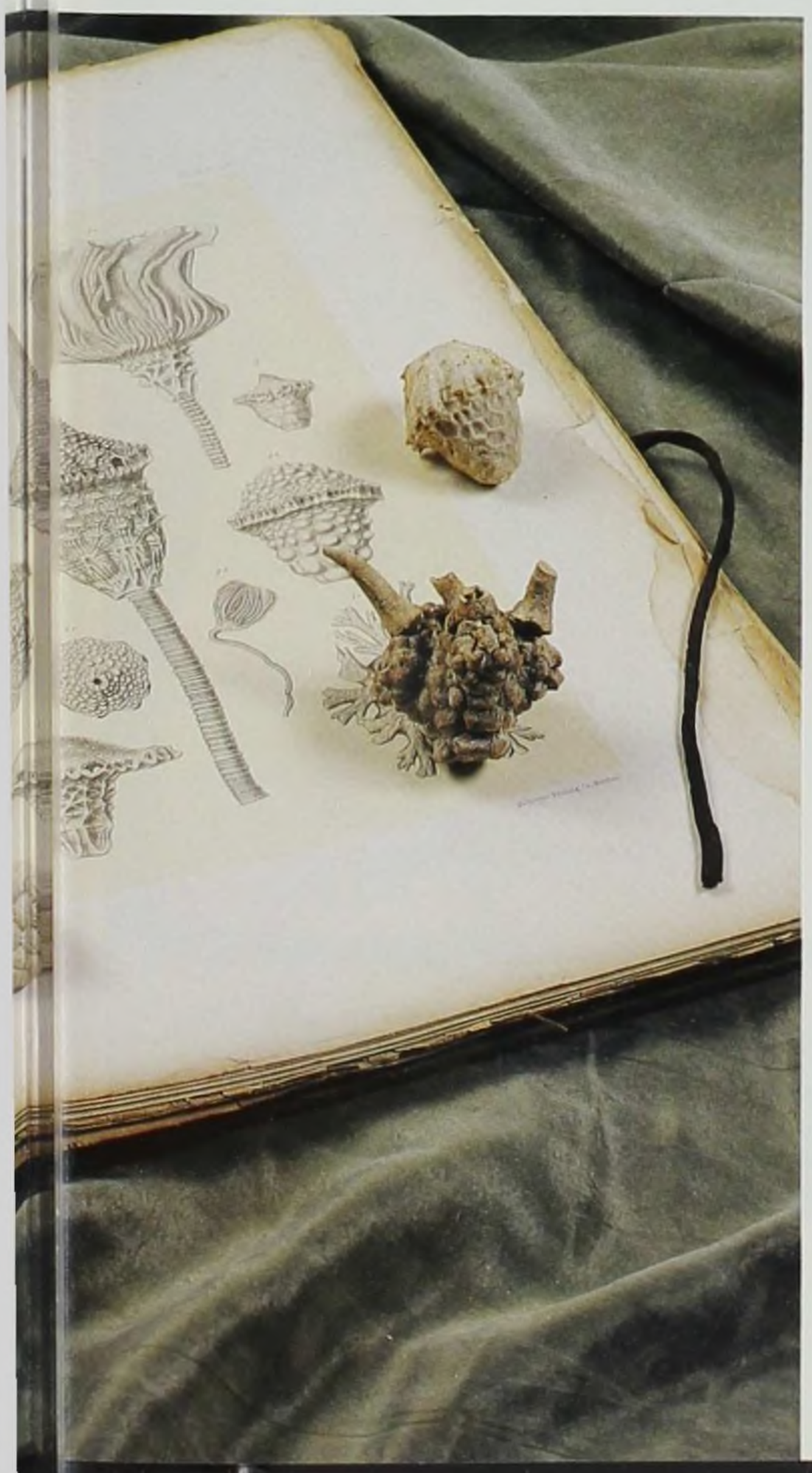

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COURTESY KAREN BEANE NORDSTRUD

Burnice H. Beane points to an individual crinoid on a large limestone slab covered with crinoid fossils.

PHOTO BY CHUCK GREINER

This species of crinoid, *Rhodocrinites beanei*, is named for Beane and recognizes his work in collecting crinoid fossils. This fossil is about the size of a quarter.

BURNICE H. BEANE was fortunate to grow up on a farm adjoining the Le Grand quarry. Over the years, his watchful eye, and those of cooperative quarry workers, spotted many chunks of limestone that likely held deposits of crinoids.

Others in Le Grand and nearby Marshalltown, such as editor Corwyn O'Neal and quarry operator George Kirby, also collected crinoids. But none amassed collections to match Beane's.

Beane discovered eleven species of ancient crinoids at the Le Grand quarry. Yet one of his most significant finds at the quarry occurred in 1931 when blasting exposed a cluster of ancient starfish, close relatives of crinoids. "The best discovery I ever made was a slab of starfish," Beane later said, "and that slab, when I saw it it was about five feet wide and about three feet thick, I think. And it took me two days to get it to work down from the wall [of the quarry] so I could move it. When I got it so I could handle it at all, I used a plank to slide it onto a truck and took it home."

For twenty-six years he worked on the 600-pound slab, scraping away the surrounding limestone to eventually reveal 183 starfish—a remarkable specimen because it is so unusual to find starfish fossils in groups of more than a few. (See page 3 for starfish detail, page 20 for more on Beane.)

CRINOIDS WERE SO ABUNDANT in Iowa's seas that their fossilized body parts are a major component of much of Iowa's limestone. Nevertheless, finding a chunk of limestone with a complete, still-assembled crinoid fossil buried within it is like finding a needle in a haystack; perseverance is vital. But the next step requires perseverance, too. "Preparing" the fossil, so it stands out in three dimensions above the surrounding limestone matrix, is tedious work, regardless of the available tools and technology. Sitting out in his yard, Burnice H. Beane used a steel probe, chisel, and hard-bristle brush. Others have used hydrochloric acid, but this tends to dissolve the fossils as well as the surrounding limestone.

In the 1960s, Richard Boyt, a museum technician at the Iowa Department of History and Archives (now the State Historical Society of Iowa), began preparing crinoids by micro-sandblasting. The Smithsonian and the Field Museum had used this technique on vertebrates, but Boyt was one of the first to micro-sandblast invertebrates such as crinoids. Society curator William M. Johnson explains the procedure: "Fine, dust-like particles of dolomite, glass, and other material are propelled by air pressure against the stone. When fossils are slightly harder than the surrounding rock, the micro-sandblasting cleans away the matrix and exposes the delicate organic structures." By varying air pressure and type of particle, micro-sandblasting can be used on materials as hard as limestone, steel, and glass, or as soft as leather. It can even remove fly specks or pencil writing from paper.

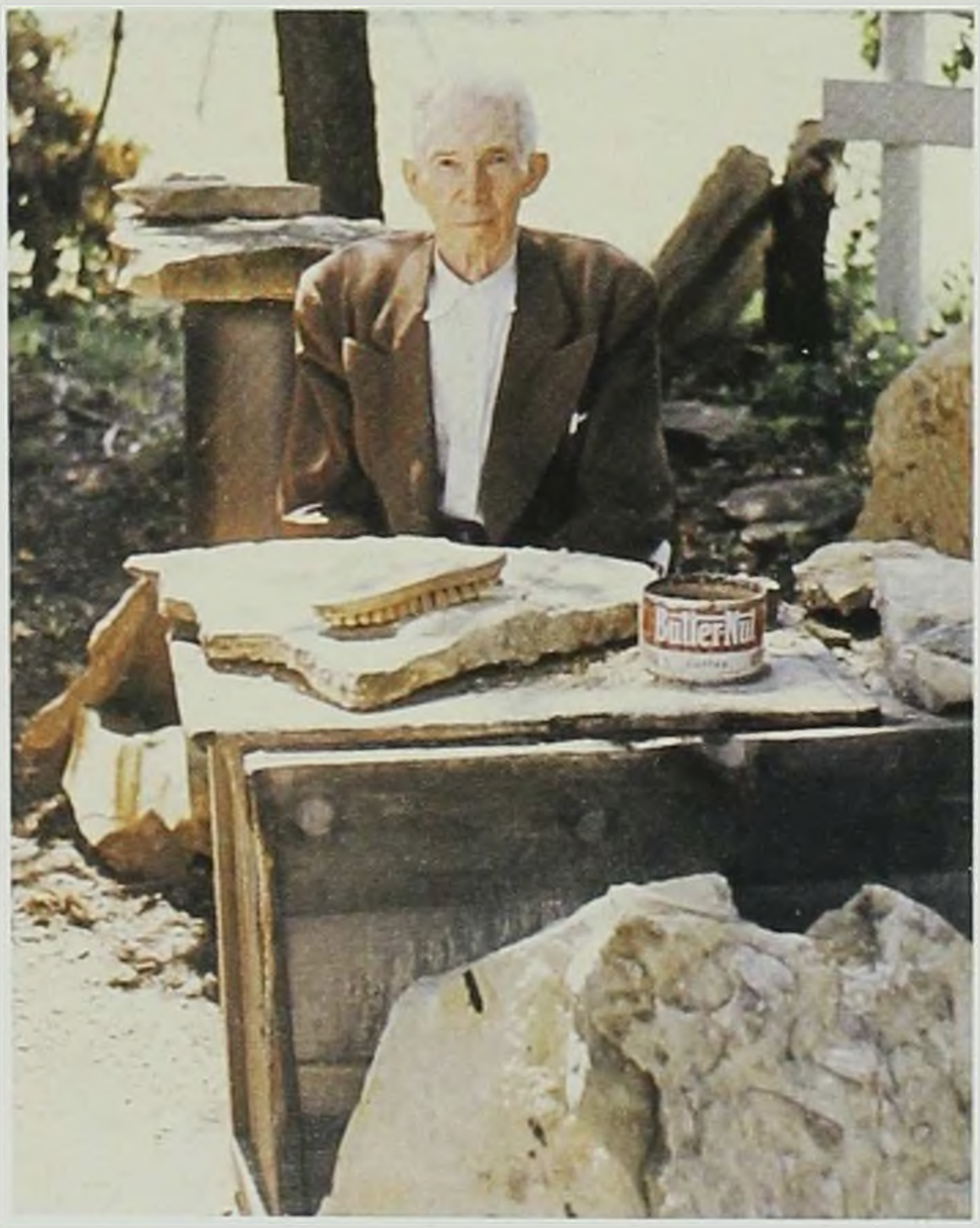
PHOTO BY CHUCK GREINER

Micro-sandblasting the limestone from the long hairs, or pinnules, on crinoids and blastoids required curator William M. Johnson's steady hand and numerous hours. Blastoids are close relatives of crinoids.

Johnson has micro-sandblasted several crinoid slabs, including the close-up above. This slab took only sixty to eighty hours because the stone was relatively soft. The slab on pages 10-11 prepared by Boyt took much longer because the limestone was harder and the mass of crinoids more complex.

"I'm fascinated by the discovery and by the intricacy," Johnson explained. "You have to feel your way through. You have to have an idea of the anatomy of the animals and to be able to visualize the shallow where they settled at the bottom of the sea floor, so you don't cut too deep."

COURTESY KAREN BEANE NORSTRUD



B. H. Beane prepared crinoid fossils in his yard, using simple tools and steady devotion.

PHOTO BY CHUCK GREINER

Society curator William M. Johnson micro-sandblasts the limestone matrix around a small crinoid specimen.

THE LE GRAND QUARRY that yielded such amazing fossil specimens through the 1930s is now overgrown, and geologists doubt if any more crinoid deposits will be found there. Quarry operations have moved north across the Iowa River.

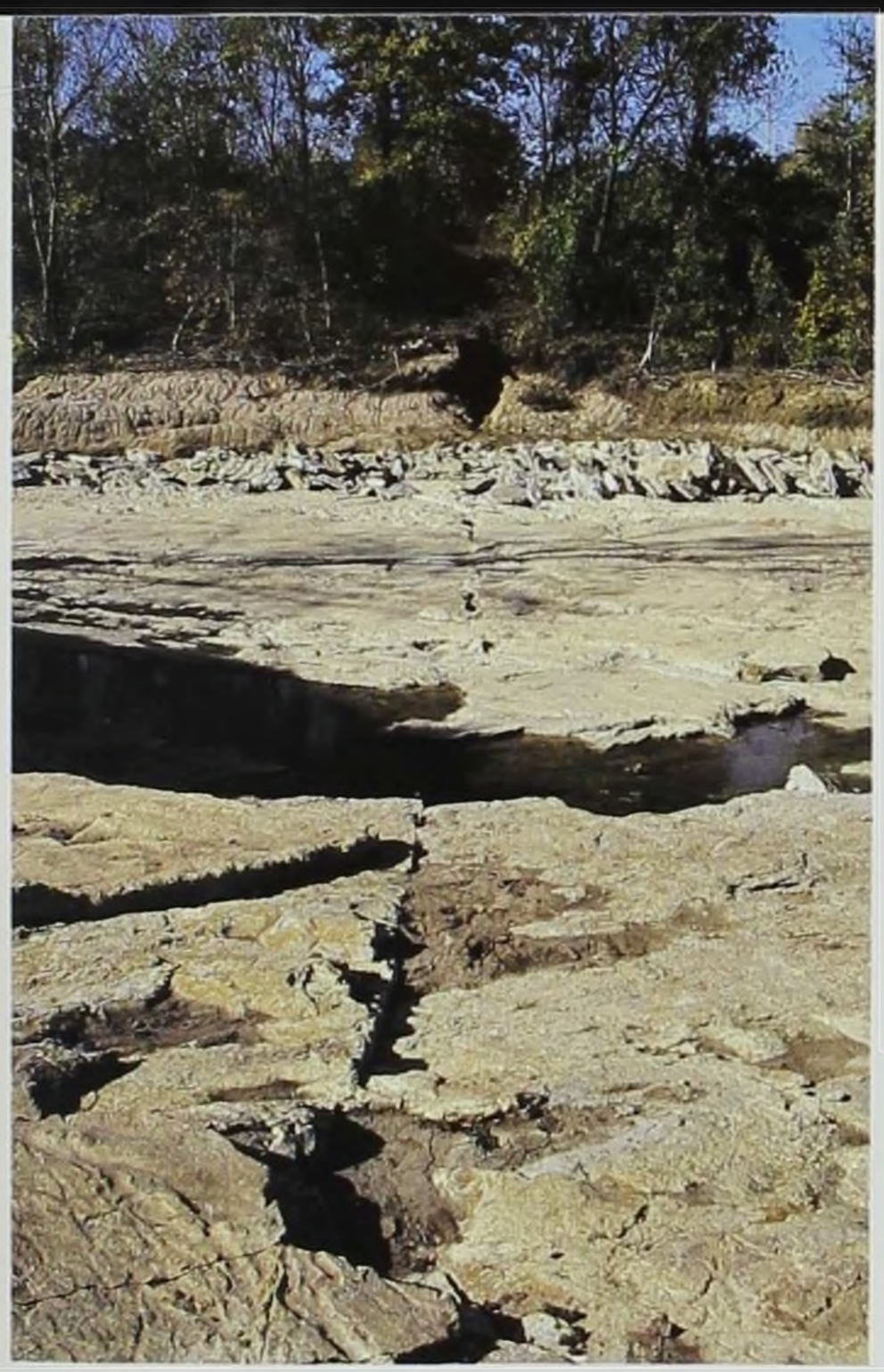
But other fossils that tell Iowa's prehistory are deep under Iowa's rich soil. Embedded in layers of limestone, sandstone, shale, and coal, fossils of prehistoric animals and plants wait to be uncovered and studied.

Sometimes it takes centuries for wind or water to erode softer rock and reveal fossils. Sometimes it takes decades—and chance—for quarry excavation to uncover fossil deposits. And sometimes, as in the summer of 1993, it takes only a few weeks.

At Coralville Lake in Johnson County (shown here), flood waters surged over the emergency spillway. In a matter of days, the rushing waters carved away as much as fifteen feet of soil down to bedrock. Geologists have named the exposed channel "Devonian Fossil Gorge" because the bedrock and fos-

PHOTOS BOTH PAGES BY RAY ANDERSON, IOWA DEPT. OF NATURAL RESOURCES

In 1993, floodwaters surged over the Coralville Lake emergency spillway, washing away trees, soil, and glacial-age deposits, and carving out a gorge down to bedrock. Alert visitors can now spot fossil crinoids, corals, and brachiopods in the limestone. Spectacular, fossil-laden slabs that would have deteriorated as people walked on them (as well as from normal weathering) were salvaged and prepared. They are now on display in the adjacent Corps of Engineers visitor center. Testimony to the power of the recent flood, the Devonian Fossil Gorge is also testimony—like the Le Grand quarry and Burlington's limestone bluffs—to the life forms that once lived in Iowa's ancient seas.

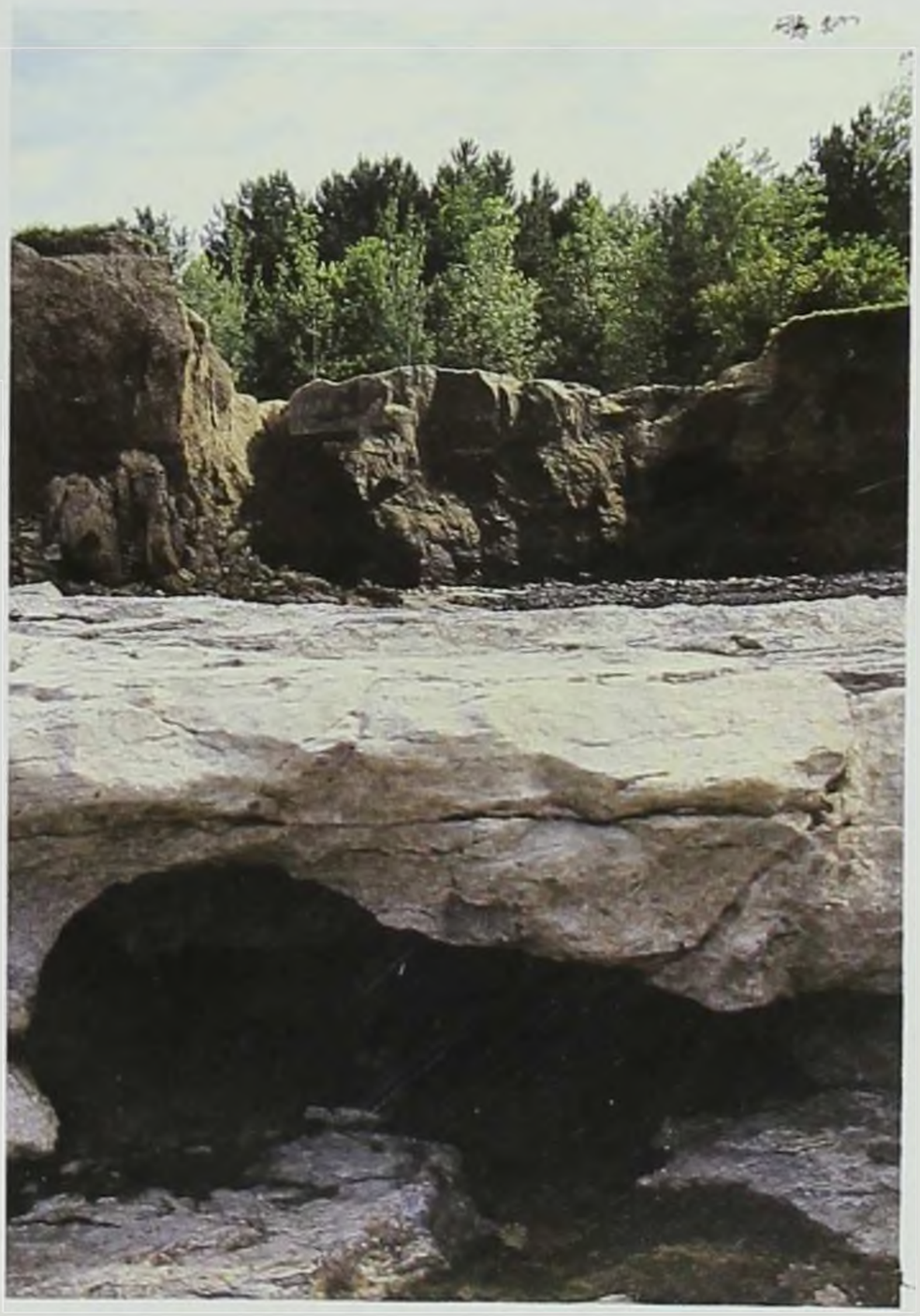


The 1993 flood revealed more than fossils at Devonian Fossil Gorge. This fracture, a plane of weakness in the bedrock, was probably formed millions of years ago and may be hundreds of feet deep. As groundwater follows such fractures and dissolves the limestone, fractures may gradually enlarge into caverns. Note in the background how the force of the moving floodwaters shoved together these limestone slabs as if they were books on a shelf.

sils date to the Devonian period, about 375 million years ago (slightly older than the Mississippian period represented at Le Grand). Within three months after the 1993 flood had receded, a quarter of a million visitors toured the gorge, essentially walking on successive floors of an ancient Iowa sea. Geologist Jean C. Prior of the Department of Natural Resources calls it a "spectacular new place in Iowa" to see fossilized corals, crinoids, and brachiopods. (This isn't the first time that Johnson County fossils have attracted attention. In 1866 Louis Agassiz lectured at the nearby state university on "Coral Reefs of Iowa City;" soon thereafter, in recognition of the area's abundance of fossil corals, a new town site northwest of Iowa City was named "Coralville.")

At Saylorville Lake north of Des Moines, the flooding Des Moines River in 1993 deepened a similar gorge into limestone, sandstone, shale, and coal, uncovering more fossils there, though they're not as accessible to the public.

Many of us will remember the summer of 1993 as a time when Iowa again seemed like a shallow sea. In fact, the surging rivers and widening streams did what our imaginations must labor to do—lift away Iowa soil to reveal the life forms of Iowa's ancient tropical seas. □



Subterranean movement of groundwater had long ago carved out this small cavern in the limestone, but it was not revealed until 1993 floodwaters below the Coralville Lake emergency spillway washed away the soil down to bedrock. Soil layers in background show amount of material washed away; various brown layers represent different glacial-age episodes, when an ancestor of the Iowa River flowed here.