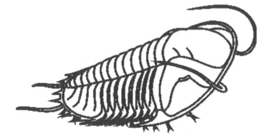
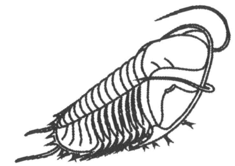
Tracking Trilobites: Adventures in Paleontology

Judy Lundquist

"They Hadn't Spoken in Years, but the Old Fossil Brought Them Together." Neckpiece by Linda Kaye-Moses. The "old fossil" is the trilobite *Elrathia.*

Kentucky Geological Survey
James C. Cobb, State Geologist and Director
University of Kentucky, Lexington





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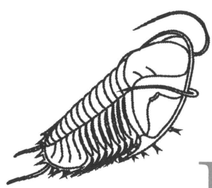

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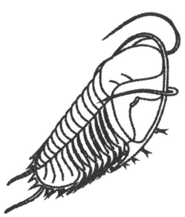

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Trilobite drawing by Sam Gon

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Our mission

Our mission is to increase knowledge and understanding of the mineral, energy, and water resources, geologic hazards, and geology of Kentucky for the benefit of the Commonwealth and Nation.

Technical Level

General Intermediate Technical

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Contents (continued)

Dedication

Tracking Trilobites: Adventures in Paleontology is dedicated to Todd Hendricks, Nigel Hughes, Dan Phelps, and George Weems, mentors and friends. Thanks to Nigel for his expert and essential technical review, and to Brenda Hanke for technical assistance.

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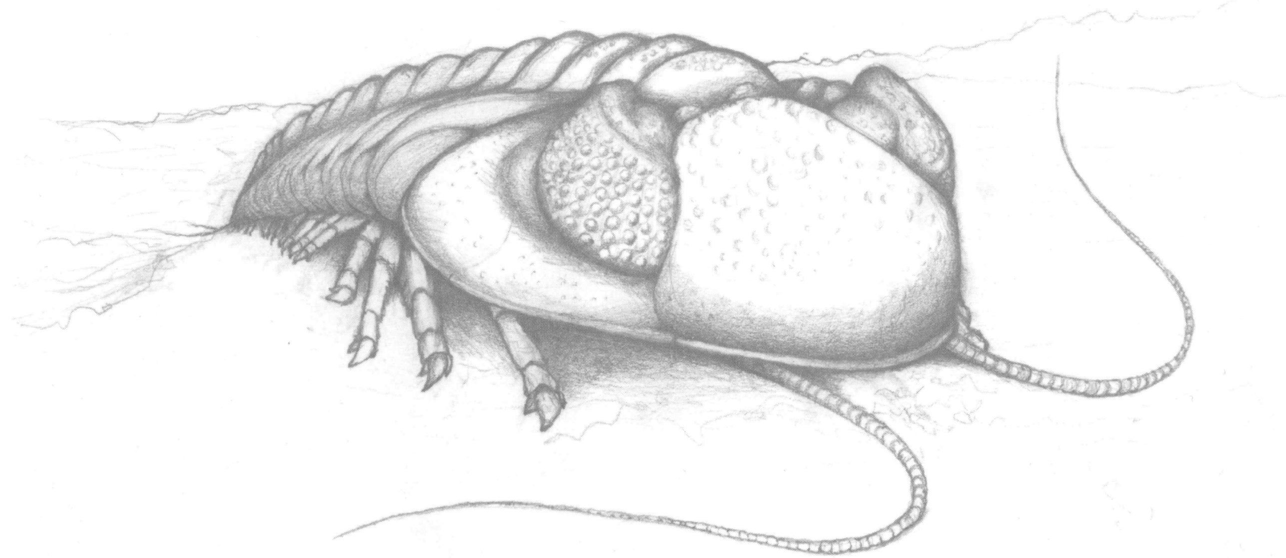
People like trilobites

If trilobites were alive today, people would keep aquariums filled with them. Unfortunately, this is fantasy. Trilobites have been extinct for hundreds of millions of years. But in nature, reality is often more fascinating than fantasy. To find a trilobite in the rocks at the side of a highway is a thrill. To pick one up is to hold millions of years in your hand. It's the closest thing to a time machine you will ever have. It can take you back to a very different world, ages before there were people, or even land animals. Most trilobites nestle comfortably in your hand. They curl up snugly in your imagination too.

Trilobites were animals that lived in the seas about 550 to 250 million years ago. Their fossils are found in many parts of the world, including Kentucky, today.



Sharon Sammons

The trilobite *Phacops* prowls the seas of Kentucky.

How to pronounce trilobite:

tri- as in sky (*not* tril- as in spill)
lo- as in low
bite
TRY-low-bite

Modern people aren't the only ones to like trilobites. Frank A. Beckwith lived in Delta, Utah, in the early part of the 20th century. Being an accomplished natural scientist, he knew the local fossils. Antelope Springs, near Delta, is famous for well-preserved specimens of the trilobite *Elrathia kingi.* When Beckwith explored a Ute burial site and found an *Elrathia,* he became curious. He asked a friend from the local Pahvant Ute tribe if he knew anything about the trilobites. According to his friend, the Pahvant name for trilobites meant "little water bug like stone house in." If you wore them, they protected you against illness and injury. In 1931, another Ute friend made a necklace for Beckwith according to the Ute tradition. This necklace had *Elrathia* trilobites strung on rawhide with clay beads. The tassels were horsehair. Beckwith was told that in the old days, the beads would have been polished stone (Taylor and Robison, 1976).

Trilobites and people go way, way back. In a late Paleolithic rock shelter at Arcy-sur-Cure in central France, archaeologists found a trilobite, possibly *Dalmanites.* It was drilled to wear as a pendant by the Magdalenian people some 15,000 years ago. The site is now known as La Grotte du Trilobite (Baffier and Girard, 1998).


Michael Taylor


William J. Nieman

"Two Worlds Joined." Stoneware bowl by Lauri and Chris Gass. The trilobite is *Balizoma.*

What are trilobites, anyway?

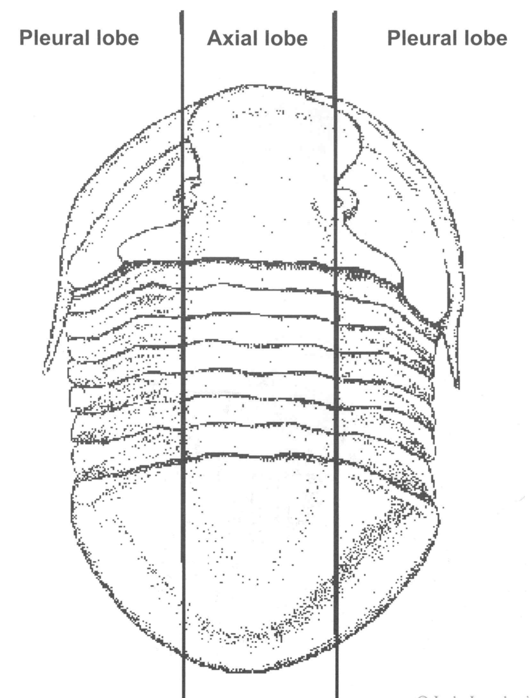
For a long time, we didn't know exactly what trilobites were, except that they were invertebrates—animals without backbones. The German naturalist Johann Walch came up with the name "Trilobitae" in 1771 (Whittington, 1992). It has since been changed a bit to "Trilobita," or, informally, "trilobite." So we had a good name for them, but we still didn't know what they were.

Scientists classify life into a series of increasingly more similar groupings. Here's a comparison of the classification of humans and trilobites:

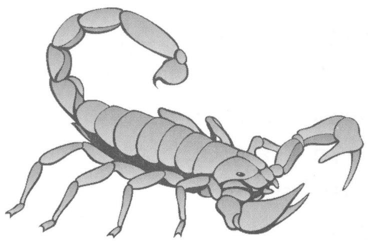
Group:	Human	Trilobite
Kingdom:	Animalia	Animalia
Phylum:	Chordata	Arthropoda
Class:	Mammalia	Arachnata
Order:	Primates	Trilobita
Family:	Hominidae	Trinucleidae
Genus:	*Homo*	*Cryptolithus*
Species:	*sapiens*	*tesselatus*

Trilobites are arthropods. Because the armor or skeleton of arthropods is on the outside of their bodies, it is called an exoskeleton. All arthropods have exoskeletons, segmented bodies, and jointed legs (arthropod means "jointed foot"). Examples are modern insects, crabs, scorpions, and spiders (Harrington, 1959). Because there are so many different kinds of arthropods, and because we keep learning more about them, scientists are only beginning to agree on exactly how different arthropods relate to each other. Studying the gene sequences of modern arthropods is making a huge difference in reaching this consensus (Nigel Hughes, 2002, University of California–Riverside, personal communication).

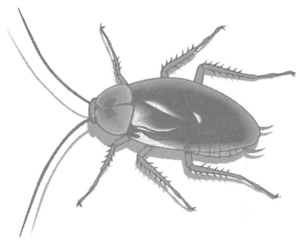
The name "trilobite" means "three-lobed one." The central, or axial, lobe (part) is the body. The two side lobes are called pleural lobes. These grew out from the central plates, covering and sheltering the limbs (Tudge, 2000).



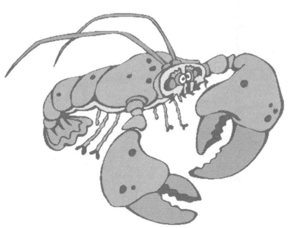
Three major classes of living arthropods:



Chelicerata *(Cheli* is Greek for "claw.")
Horseshoe crabs, spiders, scorpions, ticks, and harvestmen (daddy longlegs).



Mandibulata *(Mandere* is Latin for "to chew." Mandibulum is a jaw.) Insects, centipedes, and millipedes.



Crustacea (The Latin word *crustaceus* means "having a shell or crust.") Crabs, lobsters, shrimp, and krill.

Where do the trilobites fit in this scheme? Nowadays, scientists group animals together when they're actually related to each other, having a common ancestor, not when they just look alike. Because trilobites are extinct, figuring out which arthropods are most closely related to them is hard. None of the living classes work, exactly. By carefully studying the inherited traits of arthropods, scientists now agree that trilobites are most closely related to the spiders, scorpions, and horseshoe crabs—the class Chelicerata. Trilobites share a more recent common ancestor with the modern chelicerates than with any other arthropods. This makes trilobites and modern chelicerates sister groups (Wills and others, 1994) in the class Arachnata (Nigel Hughes, 2002, University of California–Riverside, personal communication).

Trilobites represent an order within the classification scheme. Within the order Trilobita, different kinds of trilobites were related to each other. Just as with all the arthropods, scientists have had a hard time agreeing exactly how to classify the kinds of trilobites within the order Trilobita. Different scientists might place different trilobites in different families.

Even if their family trees are a little mysterious, kinds of trilobites still have names. The name usually has two parts. The genus (a bit like your last name) comes first. It's followed by the species (sort of like your first name). So, trilobites have names like:

Genus	**Species**	
Isotelus	*maximus*	(eye-so-TEEL-us MAX-em-us)
Phacops	*rana*	(FAY-kops RON-a)
Cryptolithus	*tesselatus*	(Krip-toe-LITH-us tes-uh-LOT-us).

Determining the genus name of a well-preserved fossil trilobite is relatively easy. Identifying individual species is much more difficult, because they are often defined by subtle anatomical differences.

Genera is the plural of genus. We need the plural, because more than 2,000 genera of trilobites are known. Within the genera, there are almost 10,000 species (Foote, 1997). And scientists are finding new ones all the time. That's a lot of trilobites!

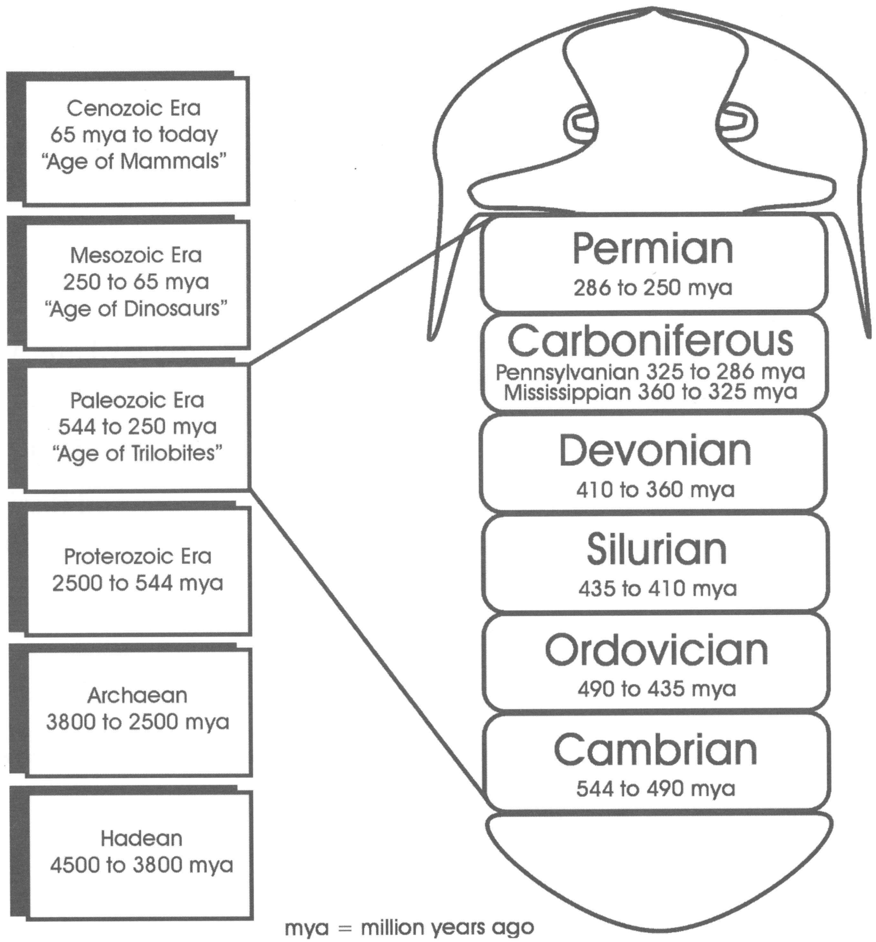
Trilobite times

As scientists like to create patterns of living things by placing them into phyla, they also like to divide time into parts. Time since the earth began is studded with billions of years. This "deep time," as it is sometimes called, is divided into chunks containing millions of years. Each chunk is set apart by some event we think is important, often something that happened with life.

Figuring out how old trilobites (or other fossils) are is easy enough, if you aren't looking for an *exact* age. Here's how it works. Most fossils are found in sedimentary rocks. Sediment is solid grains of material that settle to the bottom of a liquid, like mud at the bottom of a puddle. Sedimentary rocks get their start in just this way.

Layers of sediment build up at the bottom of shallow seas as muds, sands, and shell bits wash into them from the land, or are carried in by storms or currents. Over time (thousands or millions of years), the layers are pressed hard by more heavy layers on top of them. All the particles that make up the mud or sand get closer together, as most of the water between them is pressed out. Chemical changes may cement the particles together. The sediments then become sedimentary rock. This gives us a bunch of rock layers stacked like flapjacks on a plate. As long as these layers are not disturbed (not turned upside down by earthquakes, for instance), we know that the lowest layers are the oldest. They were laid down first. As you go up through the layers, they get younger and younger, the very youngest being at the top. The study of this system of rock layering is called stratigraphy.

Trilobites lived from the Early Cambrian Period, 544 million years ago (mya) to the Late Permian, 250 mya. Trilobites are one of the animals that define the Paleozoic Era.



A trilobite scientist

Peng Shanchi is a professor at the Nanjing Institute of Geology and Palaeontology, the Chinese Academy of Sciences. His main research interests are Cambrian and Ordovician stratigraphy and trilobites. Currently, he's working on the Cambrian trilobites from northwestern Hunan, China.

When he was a college student at the Beijing College of Geology, he saw trilobites for the first time with his own eyes, and since then that animal has become his favorite fossil. He entered the Nanjing Institute to receive his graduate training on trilobites. Under the famous late Professor Lu Yanhao, the founder of modern trilobite research in China, he received his Ph.D. He is known as the first Ph.D. holder on trilobites in Chinese history. He has been a voting member of the International Subcommission on Cambrian Stratigraphy, and a council member of the Palaeontological Society since 1997. He was recently elected the head of the Cambrian Working Group of the All-China Stratigraphic Commission.

If animals such as trilobites lived on or above the bottom—and we know that millions of them did—some of their bodies, shells, and footprints got caught in the sand and mud. As the layers became rock, the animals became fossils. As with the undisturbed rock layers, the animals that lived first are in the bottom layers and are the oldest. Those in the top layers are the youngest.

Rocks containing trilobites are found below rocks containing dinosaur and mammal fossils. This tells us the trilobites are older. Along with some other animals, trilobites define the Paleozoic Era because they are not found in rocks below that time, or above it. They are index fossils for the Paleozoic. This means that anywhere in the world, if you find trilobites, you're looking at Paleozoic rocks (Busch, 2000).

If an index fossil such as a particular kind of trilobite did not live very long, then the range of rock layers where its fossils are found will be very narrow. This allows us to divide the Paleozoic into narrower chunks of time such as the Ordovician and Devonian Periods. Paleontologists love to split these periods into narrower and narrower chunks. They have divided the Cambrian Period into an incredible number of zones based almost completely on the different trilobites within its rocks (Shergold, 1997).

But wait! Now we know that one rock layer, and one trilobite, is older than another, but that's like saying you're older than your sister. It doesn't tell you anything about how old *in years* you, your sister, or the trilobite are.

Radiometric dating to the rescue! Some kinds of elements are unstable—they change over time. Uranium, for instance, slowly changes into lead. We can measure the amount of uranium in a rock sample, as well as the amount of lead. We know how long it takes for a certain amount of uranium to change to lead. By comparing the amount of lead and uranium in the rock, we can tell roughly how long ago the rock formed.

Unfortunately, fossils don't usually contain uranium. Now we have to get clever and find another way to answer this question.

Lava, when it cools, has no lead, but it does have some uranium. So it's easy to date lava by measuring the lead-to-uranium content. If you find a layer of lava beneath (older than) the trilobites you want to date, and another above them (younger), you can then place the age of your trilobites in a range somewhere between the two lava layers. *Very* resourceful. And scientists do it just this way.

Of course, very few of us have a fancy lab where we can measure uranium and lead in rocks. Another roundabout way of dating trilobites is to rely on previously dated trilobites. If yours are the same genus or species, they probably lived at about the same time, so they would be about the same age. Rocks can be used this way, too. If you find a trilobite in rocks that you know (say, by looking at a geologic map) are of Ordovician age, then you can look on a geologic time chart to find that your trilobite is between 435 and 495 million years old (Busch, 2000).

Trilobites as state fossils:

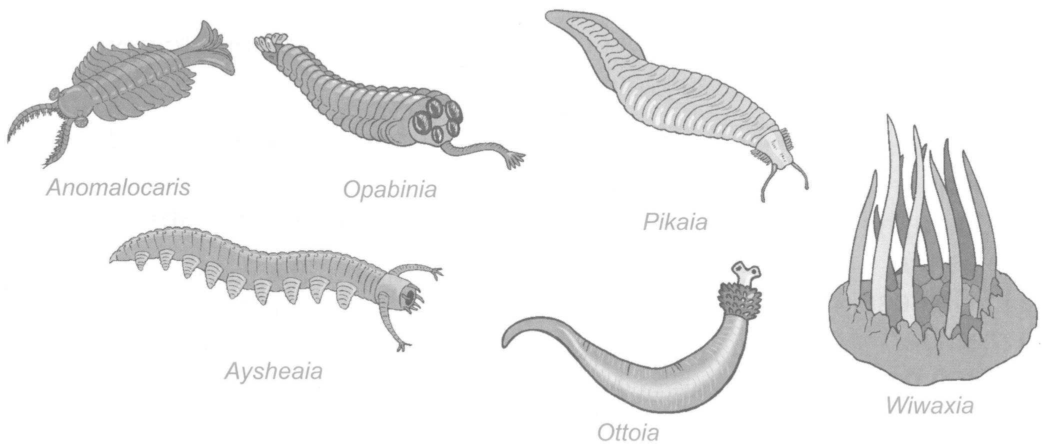
Ohio
Isotelus maximus

Pennsylvania
Phacops rana

Wisconsin
Calymene celebra

When trilobites lived

The oldest trilobites are about 550 million years old, from the beginning of the Cambrian Period. For the next 20 million years, trilobites and many other complex animals evolved. This is sometimes called the "Cambrian Explosion of Life." The numbers of different kinds of animals increased greatly. Many more kinds of complex animals led to more complex kinds of behavior, too.

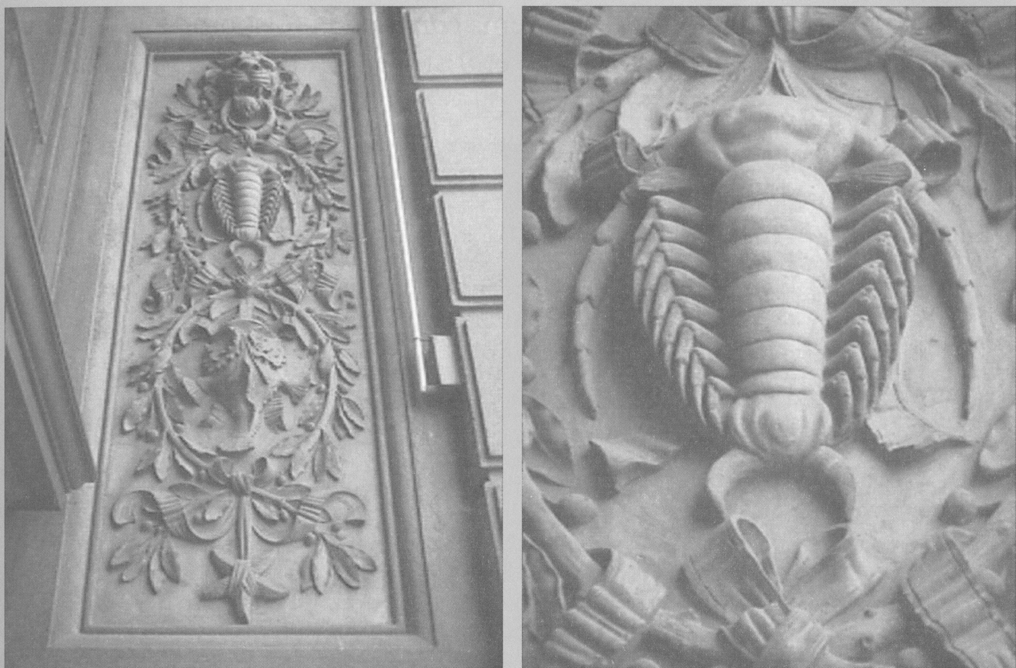


Inventive Cambrian animals.

The big question is why? Why were there suddenly so many new animals, such as trilobites, with lots of new equipment, in the Cambrian Period? It wasn't just that mineral-hardened skeletons became fossilized, making it easier for us to see life. There were plenty of new soft-bodied animals, too. Fossils such as burrows, that show behavior, became more complex too. The answers are not simple. Here are some educated guesses:

- Oxygen levels could have changed. A certain level of oxygen is needed for larger, more complex animals.
- Changes in the positions of continents, affecting ocean currents, could have changed the climate (Briggs and others, 1994).
- A toolbox of developmental genes that permitted the construction of large and complex bodies evolved (Nigel Hughes, 2002, University of California–Riverside, personal communication).
- Animals began to need armored skeletons because other animals were trying to eat them (Briggs and others, 1994).

In the end, it's still a puzzle, one of the greatest unsolved mysteries of all life. But nothing succeeds like success, and the trilobites didn't look back for 300 million years.



The National Museum of the Czech Republic, in Prague, is old and fantastic and set in the old tradition of museums (cases filled with trilobites). The trilobite sculptures on the outside of the building are not particularly modeled after any certain species. The Czech Republic is famous for its trilobites. Joachim Barrande, one of the most famous early workers on trilobites, was centered in Prague, and his collection now resides in the National Museum.

Kevin Brett

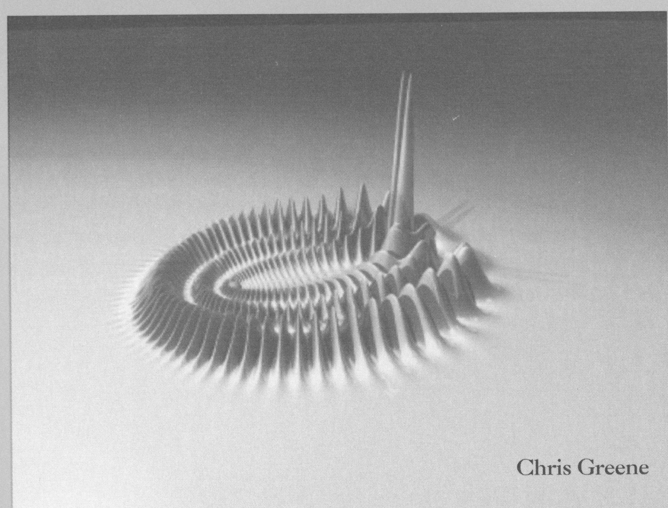
Death as a way of life

Much as we might like to have aquariums brimming and swimming with trilobites, they are hopelessly lost to us. Extinction is the normal course of things, as life grows and changes in its messy way. Many extinctions influenced the trilobites during the Paleozoic Era, before their final extinction at the end of the Permian Period.

During the best of trilobite times, hundreds of genera made homes in almost every marine (ocean) habitat. These times of diversification were inevitably followed by declines (extinctions). At the end of the Ordovician Period, a great ice age caused a mass extinction in which some trilobites and many other forms of marine life died out. Trilobites that survived may have been adapted to cooler ocean waters. It wasn't that trilobites knew that they should like colder water to make it through—just that some had adapted to earlier cooler environments, and so were already adapted to the change that occurred.

Trilobites expanded in the next period, the Silurian. Although they started with fewer families, there may have been almost as many species as earlier (Fortey, 2000b). Eighty million years later, in the Late Devonian, there was a second mass extinction, possibly related to another ice age. Low-oxygen and cooler-temperature waters invaded the shallow oceans. Shallow-water habitats may have been reduced as ocean waters were tied up in ice. The coral reefs and most of the animals living in them died out. Only a few trilobite families made it through. As conditions changed for the better for trilobites in the Mississippian Period, trilobites diversified again with new adaptations and new types to take over the habitats the other families had lived in before (Fortey, 2000b).

This seesaw pattern of extinction and diversification repeated many times, following changes in global sea level and temperature in the shallow waters. By the Permian Period, only 20 or so genera of trilobites were left. All of these survivors were adapted to warmer, tropical seas. This specialization may have made it easier for climate change to finish them off (Fortey, 2000b). By the end of the Permian Period, changes in the positions of continents had altered ocean currents, changing climate and weather patterns completely (Osborne and Tarling, 1996). The very last of the trilobites seem to have been gone by the next great mass extinction at the end of the Permian Period (Fortey, 2000b).



The "trilobite molecule." This is a computer model of a very strange form of the element rubidium. Two rubidium atoms are surrounded by one very fast-moving electron. The trilobite shape shows all the places where the electron can go. Physicists think they might know how to actually make a "trilobite molecule," but they haven't done it yet. The model really has no connection to trilobites, it just reminds us of one.

Trilobite places

Trilobites lived in both deep and shallow seas around the world. We know they lived in salt water because their fossils are found with fossils of other animals that lived in the ocean, such as crinoids (sea lilies), sea stars, sea urchins, and brachiopods. They are never found in rocks that were deposited on land or in freshwater environments.

Many of the shallow-water environments of the ancient Paleozoic oceans were home to trilobites. The maps on the next page show what the world may have looked like during the times when trilobites lived in what would later become Kentucky.

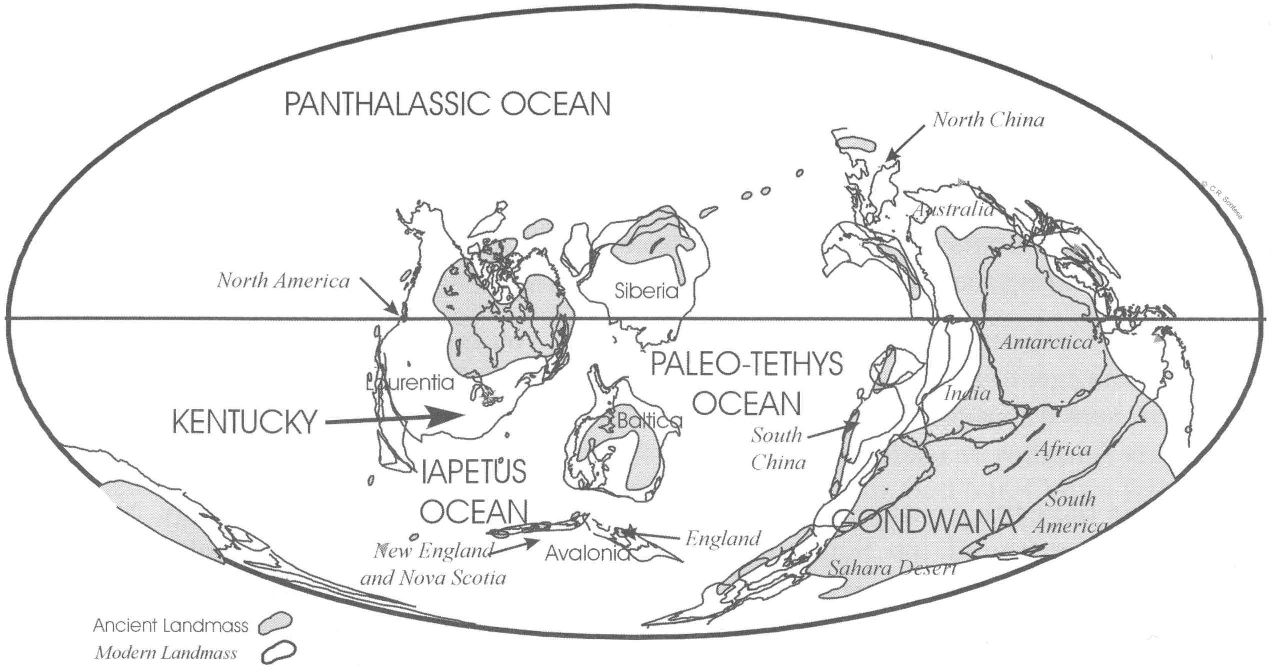
Looking at maps showing the earth during the heyday of the trilobites, you might wonder, how on earth do we know where the oceans and continents were 450 million years ago, or their shapes, or anything about them? Although there is much uncertainty about things that far back, scientists use several tools to help determine how the earth has changed through time. The location of trilobites is one of the tools used. So the little arthropods are not only fun, they're useful as well.

Powered by heat deep within the earth, continents move around at the surface, slowly—very slowly. Not only do they move around, they break into pieces. The pieces move around, too. Sometimes they collide and squish together to make new continents. It's as if you made a quilt with many pieces, but then you wanted to change it. You could just take all the pieces apart, and put them together in a new pattern. Using the same old pieces, you would have a new quilt. When nature makes the continental quilt, however, there's a new wrinkle. Nature sometimes cuts up the pieces themselves, changing their shapes, and puts *those* together in new ways. Then she arranges the reshaped pieces into a new quilt pattern. Reconstructing how the ancient continents were put together can get pretty complicated.

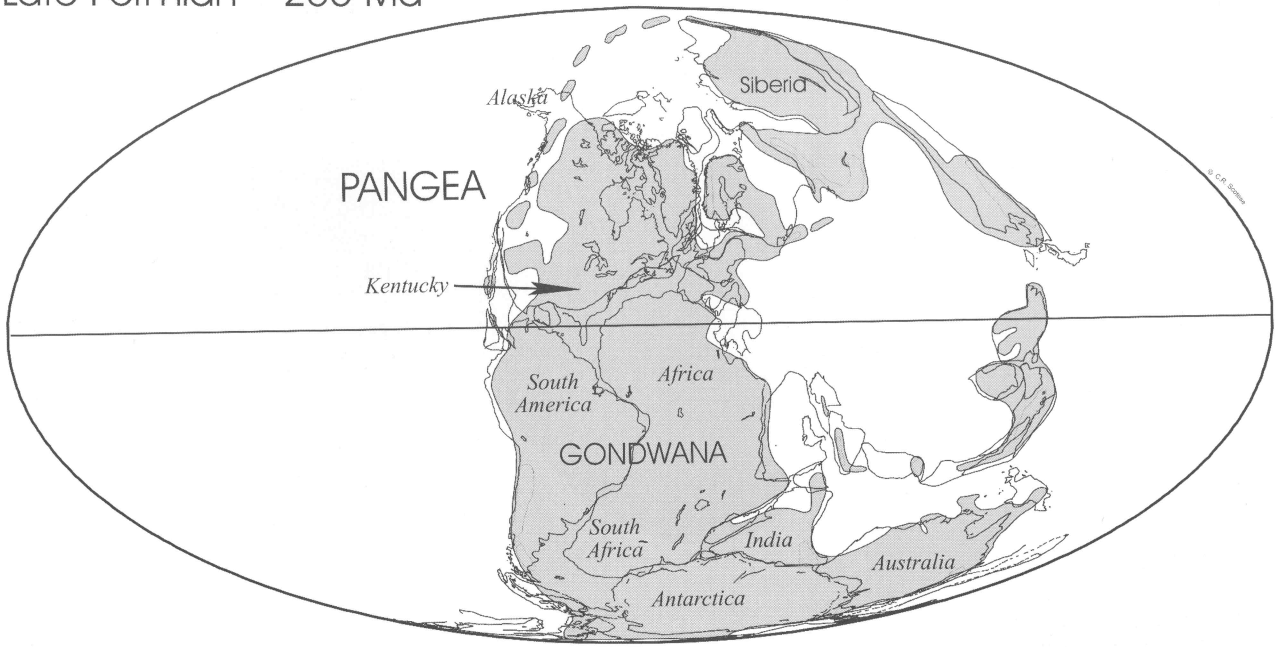
I. Jancarikova

In 1902, the sculptor Vilem Amort made an elaborate ceiling in the town hall of Beroun, in the Czech Republic. This work, which still stands, features trilobites from the region around Beroun. The area has a longstanding tradition of trilobite collecting and science. The central photo shows how the trilobites fit on the ceiling. The closeups show *Cheirurus* (left) and *Deanaspis* (right).

Middle Ordovician 458 million years ago



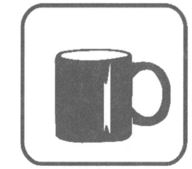
Late Permian 255 Ma



Maps modified from plate tectonic reconstructions by C.R. Scotese, PALEOMAP Project (www.scotese.com). Modified with permission.

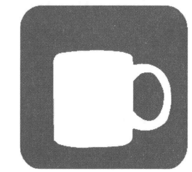
Seeing what's not there

Here's a different way of looking at things: place some object, like a cup, on a table. Looking at the cup, you can see the flat shape of it—it may be a rectangular shape with a ring on the side. Now look at everything *around* the cup, but not at the cup itself. You will see a lot of space with a cup-shaped hole in the middle. Artists seem to have beat the scientists to giving this a name—they call it negative space.

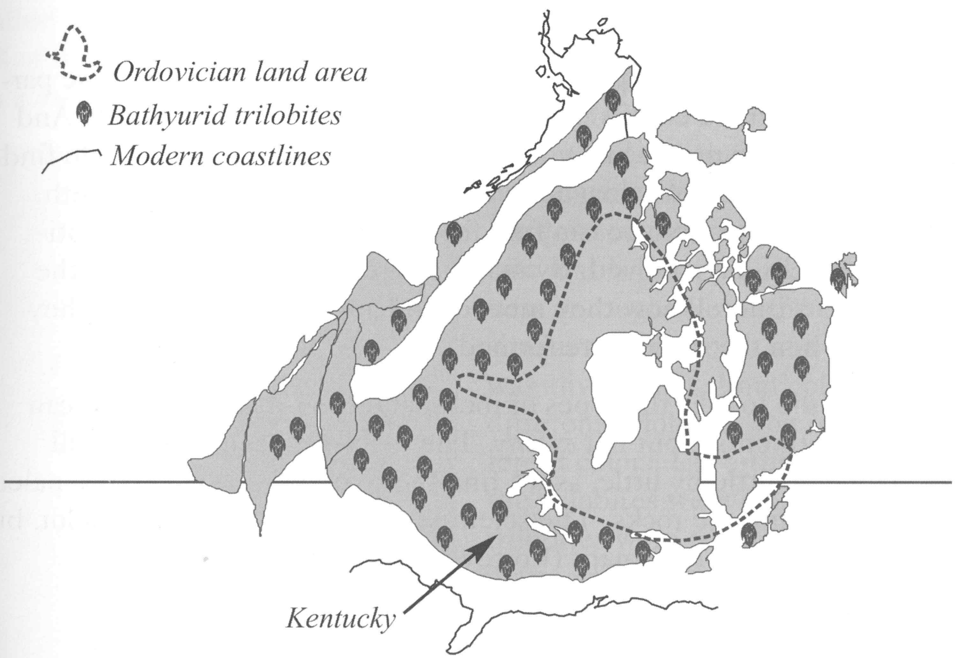


Cup with negative space around it.

Now we're going to use the tool of negative space to take a look at a continent that's not there. Continents are actually bigger than their land areas. Part of the continent extends outward from the land, under the water, before dropping off into deep ocean. We know that trilobites swarmed around the shores of the land areas of continents. If we can find enough trilobites, and map them, they will show us a negative space, with a land-shaped hole in the middle. Here's what that might look like if a squarish continent had a cup-shaped land area.



Squarish continent with cup-shaped land area.



Continent of Laurentia as revealed by its trilobites (and other sea animals). Map adapted from plate tectonic reconstructions by C.R. Scotese, PALEOMAP Project (www.scotese.com). Adapted with permission of C.R. Scotese.

Here's how it works for real: the Ordovician continent that later became North America is called Laurentia. A family of trilobites called Bathyuridae lived around the edges of Laurentia. Now, wherever we find bathyurids on the North American continent, we know the place they were found was close to the edge of Laurentia during the Ordovician. They have been found in New York, on Newfoundland (at least on the western side), and on Ellesmere Island in the Canadian Arctic. They have been found in Alaska, and down through western Canada into the western United States. Nevada, Utah, and Idaho have them. So do Texas, Oklahoma, and the states eastward to the western edge of the Appalachian Mountains, including Kentucky. There is a space in between, like the cup, where *no* trilobites are found. Scientists infer that the area in which no trilobites or other marine fossils are found was land. So this is what the continent of Laurentia looked like during the Ordovician—a lot of trilobites, with a land hole in the middle.

A trilobite scientist

I was raised in California, and developed a taste for nature during frequent trips to Yosemite National Park. My earliest recollection of collecting fossils was during trips with my father into the Kettleman Hills, where marine Pliocene-Pleistocene deposits abound. I had read extensively about my two loves, horses and fossils, by the time I entered the University of California. I immediately declared a geology major. During my graduate work, I met my future husband, Mike McCollum, also a geology student. Mike had some experience collecting Cambrian trilobites from the Great Basin, but it would be some years before we had the opportunity to turn our interest in them into professional research. Eventually, we signed a contract with Gulf Oil Company to do a survey of the Cambrian System in the Great Basin. We measured, described, and collected Cambrian faunas—including trilobites—from over 100 mountain ranges. I joined the Geology Department at Eastern Washington University. My first priority was to publish my Ph.D. work. I did not get further involved with trilobites until I joined forces with Dr. Frederick Sundberg. Since then, we have collaborated on describing the earliest Middle Cambrian trilobites in the southern Great Basin.

—Linda McCollum

Of course, trilobites are not the only way we can see Laurentia. Whole communities of fossils are used. Also, the types of rocks found on land and under the sea are different and are used to show what was land and what was sea. But that still leaves the question of *where* Laurentia was. For one thing, we know it was in the tropics. The rocks most of the trilobites are found in are limestones, which form in warm tropical seas. So sedimentary rocks are part of the answer.

Another clue is magnetism. Here's another experiment: find a rock and put a compass on it. Take a picture of the rock and compass. When you look at the photo, every which way you turn it, you can still tell which way the rock was pointing.

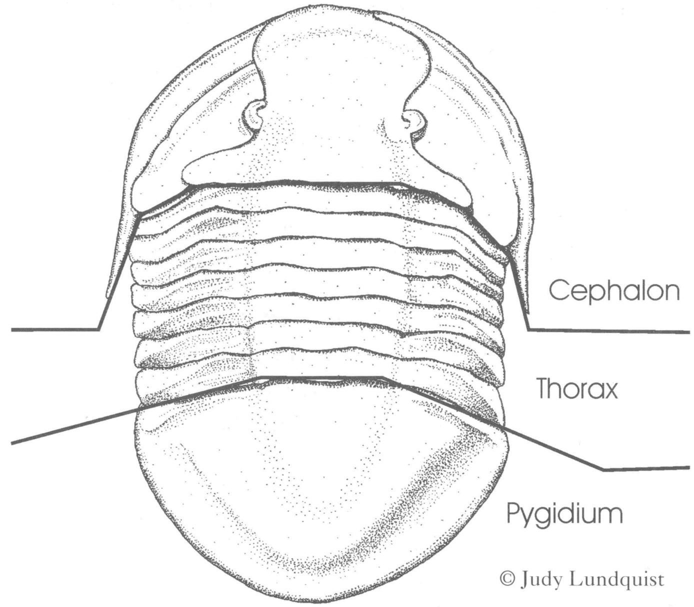
When rocks are formed, if they contain any magnetic minerals, those particles wind up aligned to the earth's magnetic poles, pointing north–south. And they usually stay where they are, like your photo of the compass. But we do find certain undisturbed rocks, whose magnetic minerals do *not* point north–south. Very odd. The best explanation we can find for this anomaly is that the continents carrying the rocks have moved. By making careful measurements of the magnetism, scientists can tell how they moved, and approximately where they would have been when the rocks were formed.

So between the fossils, the types of rocks, and their magnetism, we can map the ancient continents—but not *exactly*. The maps we have now are still shifting and changing, little by little, as we find more fossils, measure more paleomagnetism, and look at more rocks. The scientists doing this work argue a lot, but this just helps tease out the true maps (Fortey, 2000b).

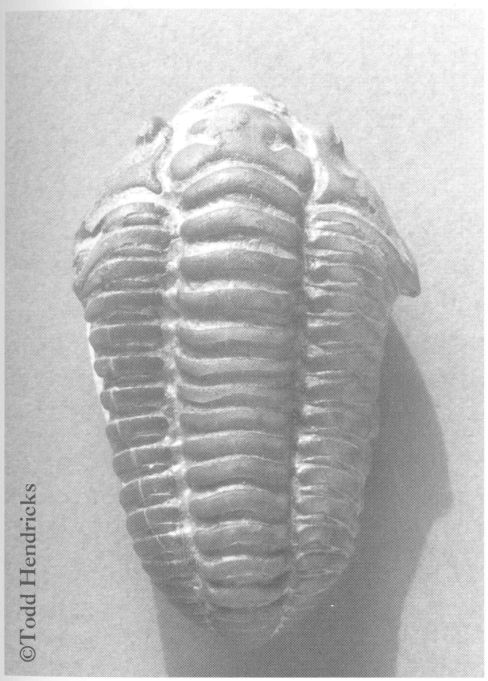
A close look at trilobites

When paleontologists set out to satisfy their curiosity about what trilobites were like, and how they lived, they're never able to get all the answers from one trilobite. The picture builds up, bit by bit, over years of work with many fossils. A missing detail is supplied by another fossil here, and another scientist, there. Whenever anyone finds out something new, he or she publishes the information for other scientists (or anyone else) to see. They can then confirm or disprove the new information by testing the interpretation. They may argue about whether the facts have been correctly understood. They may figure out new ways to find out. Over time, this multiple testing process weeds out blunders, and gets scientists closer to understanding trilobites.

Pick up a trilobite fossil and hold it in your hand. If you don't have a trilobite fossil handy, check out this photo. The first thing you'll notice is the fossilized exoskeleton, called a carapace. This hard armor covered the back of the trilobite. We think that almost all of the rest of the trilobite was soft tissue, covered by a tough, flexible outer covering, in a manner similar to that of living arthropods (Levi-Setti, 1993).



The three lobes that give the trilobite its name are usually easy to see. There is also a division of the body that is perpendicular to the lobes. These divisions are the cephalon (head), thorax, and pygidium (tail). Some people think these are the three lobes, but trilobites were named for the axial and pleural lobes.



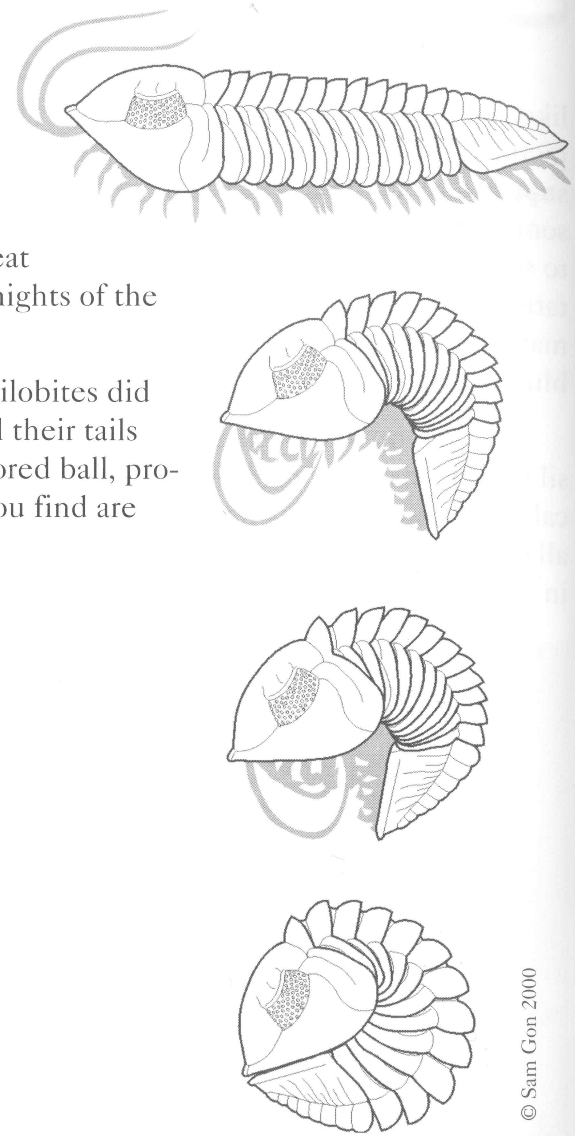
Flexicalymene meeki.

Look at the surface of the carapace. If you have a real trilobite fossil, use a magnifying glass. Do you see tiny pits, bumps, or lines? Some trilobite fossils have them, others don't. The smoothness or roughness of the carapace is probably similar to the appearance of the trilobite when it was alive. What about color? If you look at several different trilobites, you may see that they are different colors. Unfortunately, the colors of the fossils probably don't have much to do with the colors the trilobites were when they were alive. The colors come from the minerals in the rocks where the trilobites were fossilized. The colors of trilobites when they were alive were probably similar to modern marine arthropods, such as crabs and lobsters.

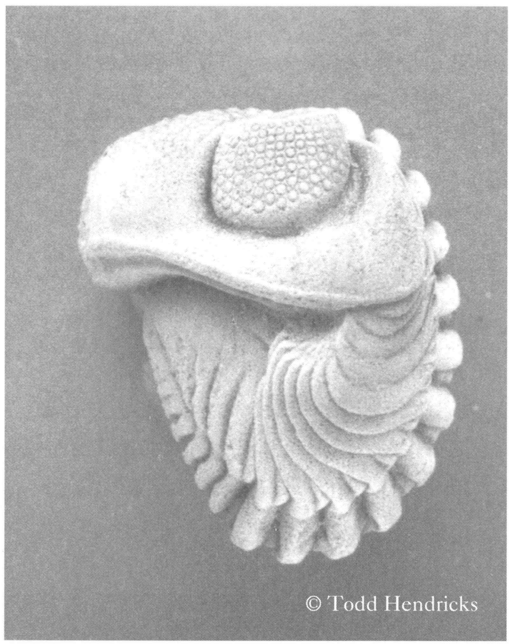
Notice the repeating, jointed segments, a trademark of all arthropods. You can find as few as two, or as many as 61 segments (Pocock, 1970), depending on what kind of trilobite you're looking at and the age of the trilobite when it died (Levi-Setti, 1993). The region between the head and tail is called the thorax. All the segments of the thorax look pretty much the same, but they're bigger near the head, and gradually get smaller toward the tail (Harrington, 1959).

With all this hard armor covering the trilobite, how did the animal move? The back edge of each armor segment fit over the front edge of the one behind it. In many trilobites, each segment also had complicated systems of ridges and bumps that fit into grooves and hollows in the next segment. As in modern arthropods, these joints held the segments together very neatly and with great strength, while allowing the animal to move (Harrington, 1959). Many millions of years later, the Knights of the Round Table would adapt this arthropod body style to make suits of armor.

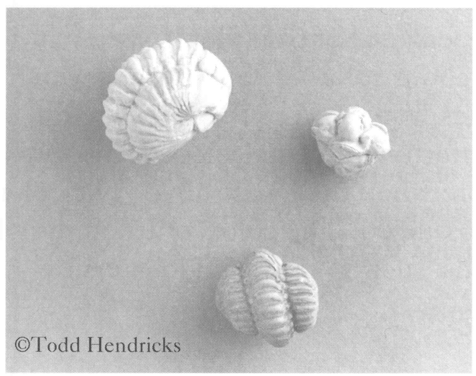
This system of *articulation,* or joints, did not work very well for side-to-side bending. What trilobites did best—and they were *champions* at this—was a forward bend. Many trilobites could curl forward until their tails came right up under the bottom of their heads. If danger threatened, they could roll up into an armored ball, protecting all their soft parts inside (Whittington, 1992). We call this *enrollment.* Many fossil trilobites you find are enrolled. Some trilobites could also bend backward (Hughes and Cooper, 1999).



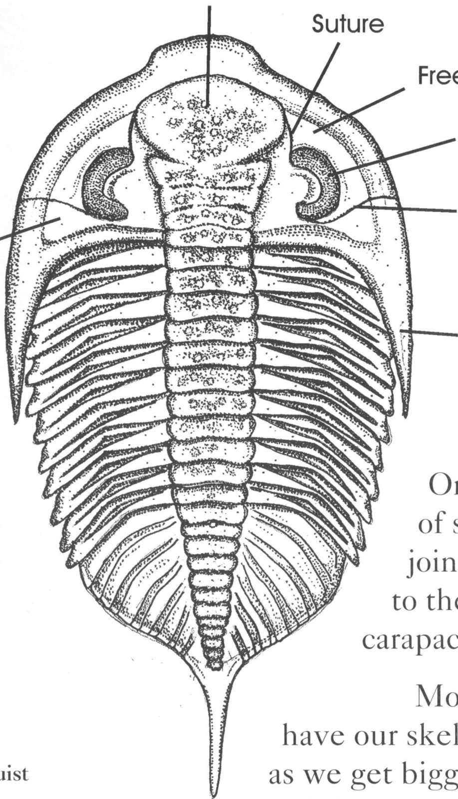
Acaste downingiae enrolls. From Gon (2001).



Enrolled *Phacops.*



Enrolled *Gravicalymene.*



© Judy Lundquist

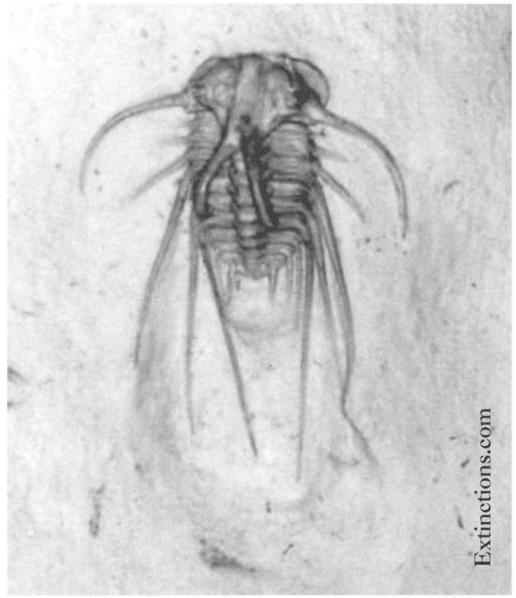
Now check out the front end of a trilobite. It looks like a shield with bumps. This is the head, and is called a cephalon. The cephalon carried important sensory organs such as eyes, and some of the feeding gear (Harrington, 1959). It's not unlike your head, in that way. The trilobite's tail is known as the pygidium. Like the cephalon, the pygidium is made up of segments fused into a single plate.

Some trilobites were covered with spines. They could come in handy as a defense if another animal tried to eat the trilobite, but they may have had other uses as well. Spines on some trilobites may have kept them from sinking into mud (Whittington, 1997a), or may have helped them float at the surface of the water.

Jumping out of their skins

On many trilobites, you can see a symmetrical pattern of suture lines (cracks where parts of the cephalon were joined together) on the cephalon. These were important to the trilobite because they allowed it to molt, or shed, its carapace. Most living arthropods do this as they grow.

Molting is really weird—at least to us mammal types who have our skeletons on the inside. Our skeletons simply grow with us as we get bigger. Having your skeleton on the outside, as an arthropod does, seems really, well, inside out. And if your skeleton doesn't grow … you're trapped. But of course the trilobites, and all the arthropods, have that problem solved. When an arthropod grows too big for its exoskeleton, it sheds the skeleton, in a process called molting. The old exoskeleton cracks and comes apart in just the right way, so that the soft-bodied trilobite inside can escape. Then the "naked" trilobite grows a new, bigger exoskeleton. A few—very few—trilobite fossils have been found that were in the soft-bodied stage. They died and were buried before their new exoskeletons hardened. These fossils are interpreted as soft-bodied because they are very thin and wrinkled, compared with other specimens from the same rock (Whittington, 1980).



Diacranurus. Photo courtesy of Extinctions.com.

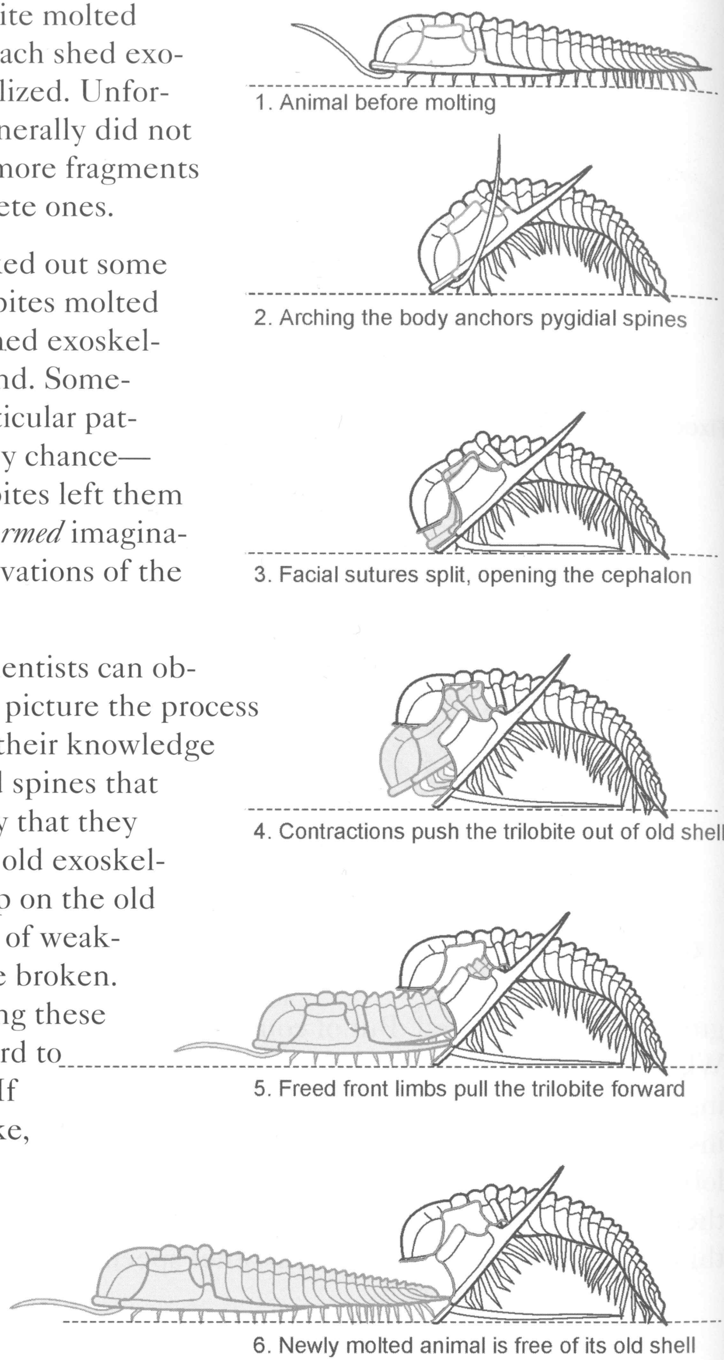
Trilo-bits. A rock covered with *Flexicalymene* and *Isotelus* bits.

Most of the trilobites found as fossils are molted exoskeletons. Each trilobite molted many times over its lifetime, so each shed exoskeleton had a chance to be fossilized. Unfortunately, the molted carapace generally did not hold together. So we find many more fragments of trilobites as fossils than complete ones.

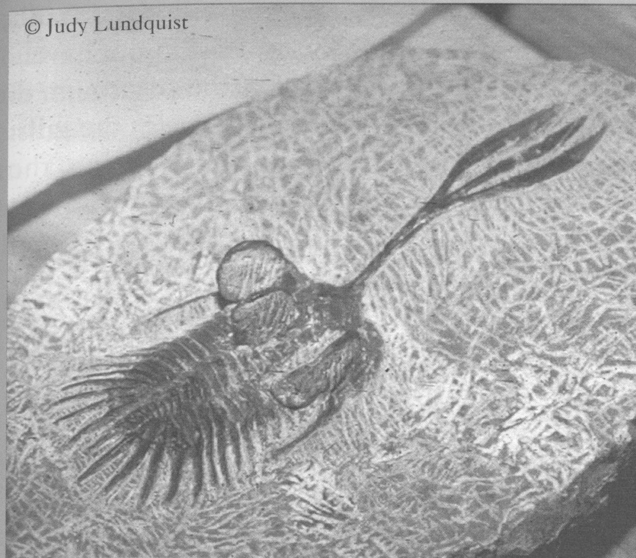
Paleontologists have worked out some interesting ideas about how trilobites molted by looking at fossil molts—the shed exoskeletons that the trilobites left behind. Sometimes these are arranged in a particular pattern that cannot have been just by chance—they were found just as the trilobites left them (Whittington, 1997a). This is *informed* imagination—the ideas *must* fit the observations of the fossils.

Encrinurus (top) and *Cheirurus* (bottom). Molting often gives us disembodied trilobite heads.

What informs the imagination? First, scientists can observe modern arthropods molting to help them picture the process in trilobites. Second, paleontologists call upon their knowledge of the body of the trilobite. Many trilobites had spines that pointed backwards, for instance. It seems likely that they would have crawled out of the front end of the old exoskeleton. Otherwise, the spines could have hung up on the old exoskeleton. Looking at the suture lines (areas of weakness) reveals where the exoskeleton could have broken. Many of the fossil molts are indeed broken along these lines. Most trilobites (not all) could bend forward to enroll, and could bend backward at least a bit. If the trilobite bent strongly, and the sutures broke, would that add up to a graceful exit from the exoskeleton? And would the exoskeleton have been left behind in the patterns we find?

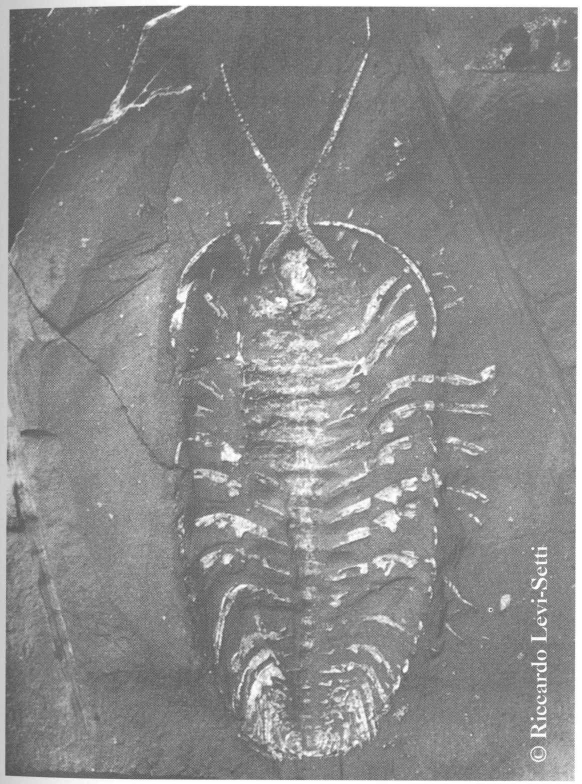


Paradoxides molts. From Gon (2001).



Unnamed trilobite from Morocco.

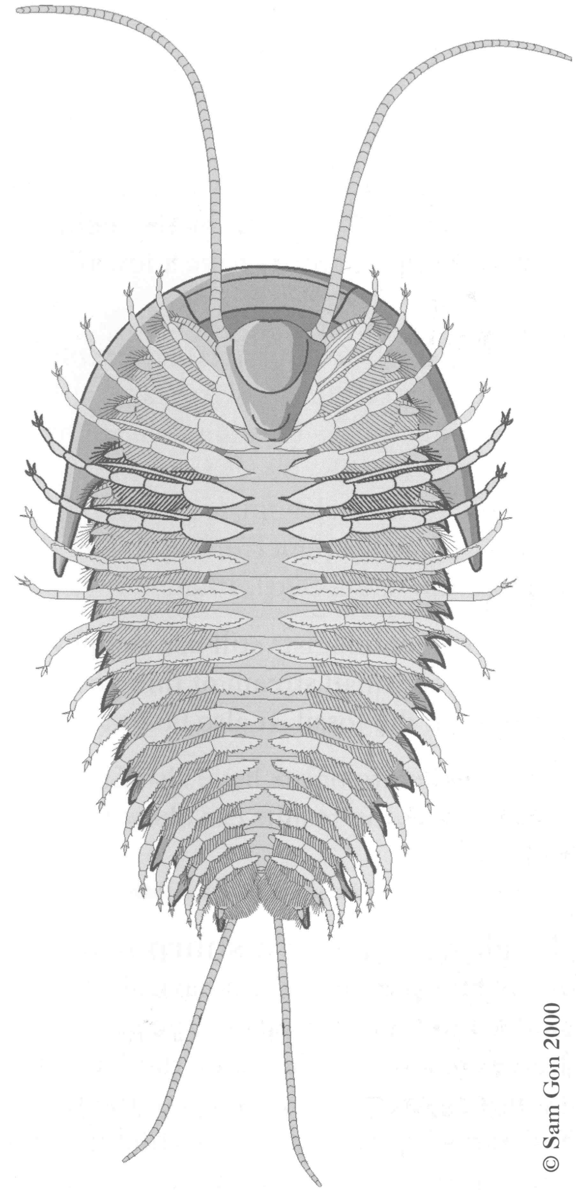
What about trilobites that had forward-pointing spines? They could not have just walked forward out of their exoskeletons. Can you think of a way they could have molted?



Triarthrus etoni Hall, prepared with an eraser by C.E. Beecher. Photo from the book *Trilobites* [2nd ed.], by Riccardo Levi-Setti (1993). Reprinted with the author's permission.

Now, let's turn the trilobite over and look at the bottom.

Oops! If you're looking at a real trilobite fossil, chances are you can't see a thing on the bottom. Either it's just rock, or the trilobite is enrolled. Trilobite fossils that have anything underneath (such as legs) visible, are incredibly rare because most fossil trilobites are just molts. The illustration—and your imagination—will have to do.



Bottom side of a live trilobite. From Gon (2001).

Imagine your trilobite is alive. Hold it in your hand, and gently turn it over on its back. Don't scare it—it might enroll! If it doesn't, the first thing you'll see is legs—*lots* of waving, prickly legs. Each segment of the thorax has a pair, and the cephalon and pygidium have some too. They are made up of jointed segments. Behind the cephalon, right up to but not including the last segment of the pygidium, the legs have two parts, or branches. The trilobite uses the bottom branch for walking, digging, or swimming. The top branch carries the gills: fringy organs that absorb oxygen from the water flowing over them. They also pass waste carbon dioxide from the trilobite's body into the water (Levi-Setti, 1993). Speaking of water, you couldn't keep your imaginary trilobite out of the water too long, because it needs the water to breathe.

With real trilobite fossils, seeing the complexities of trilobite legs and gills can be difficult. In order to see details of the fossils in the rock, trilobite scientists have a few tricks up their sleeves.

Trick number 1: a pencil eraser

Soft parts, in certain trilobites, are replaced by fine crystals of the mineral pyrite (fool's gold). You can easily see them if you remove the rock surrounding them. This is a delicate operation. If the scientists don't stop in time, they will remove the very leg they're looking for. The paleontologist C.E. Beecher, in the late 1800's, hit upon a clever way of polishing the rock away. Much as you might clean dirt off a sink by scrubbing with a cleaning powder, he rubbed the rock away with a very fine powder. Since he needed to do this very delicately and slowly, he rubbed with a pencil eraser. It worked! He "erased" the rock from about 60 trilobites, bringing to light details of the limbs and gills never seen before (Levi-Setti, 1993).

Paleontologists still use the powder trick, but the pencil eraser has given way to a high-tech machine called an air-abrasion unit. It blows a very small stream of fine powder onto the rock, gradually rubbing it away. This works best if the powder is harder than the rock, but softer than the fossil. It also takes a light touch. Too heavy a hand, and the fossil is erased before your eyes!

Paleontologists have also figured out ways of dissolving rock away from the trilobites using acids. If the acid dissolves the rock, but not the trilobite, the results can show fine detail. This has been especially important in discovering tiny details about the legs and gills (Whittington, 1997b).

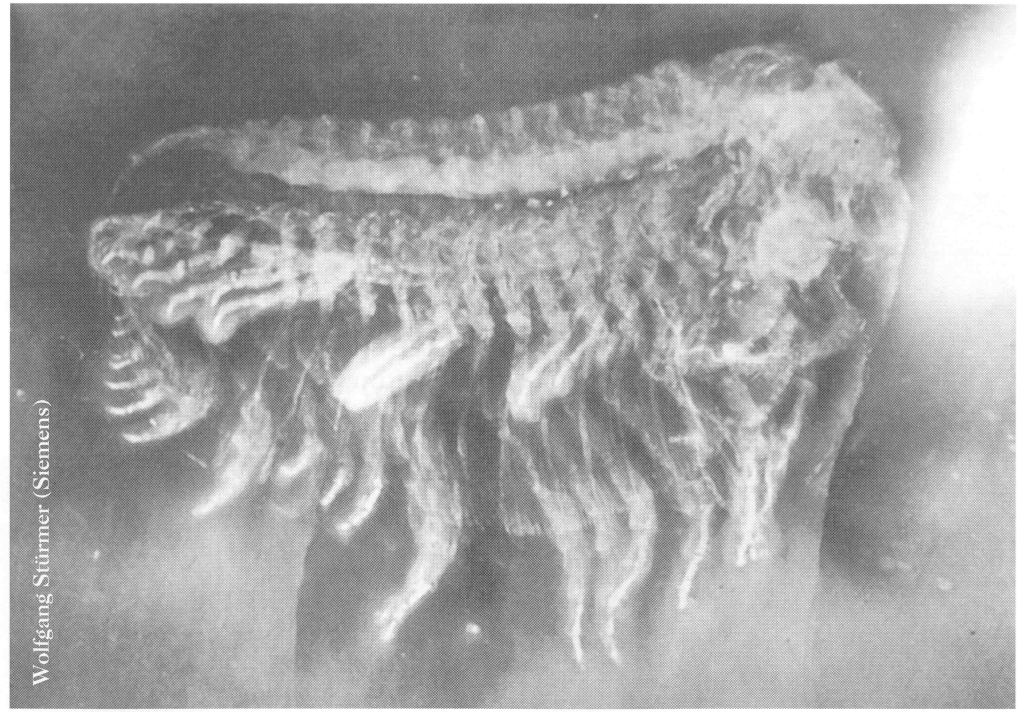
Trick number 2: a sharp knife

Enrolled trilobites, which have all their limbs hidden inside, can be sliced like a banana. C.D. Walcott pioneered this method with trilobites in the 1800's. Occasionally, the series of slices, or sections, as they're called, can be studied to see the structures and positions of the limbs. Later on, to get more detail, the Norwegian paleontologist Leif Stormer sectioned by taking pictures. He made a photograph, then ground away an extremely thin layer of the trilobite. Another photo, then more grinding. This resulted in a series of photos that the scientist used to follow each part through the trilobite's body (Whittington, 1992). Needless to say, when you do this, in the end there is no trilobite left! But the hapless trilobite has given us something very special—a database rich with information.

Trick number 3: X-rays

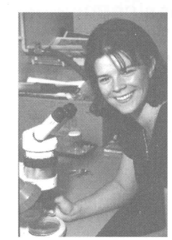
If you break your arm, the doctors take an X-ray that shows the inside of your arm. The same trick works with some trilobites. Scientists use X-rays to section trilobites without destroying them. They take an X-ray of each slice. X-rays work really well with pyrite replacement—any part with pyrite shows up beautifully. Careful study of a series of X-rays can show details of the fossilized legs, gills, and in exceptional cases, even internal organs (Whittington, 1992).

Besides legs and gills, trilobites also had some hard plates on their undersides. A bit of carapace covered the edges. This is called the doublure. It formed a narrow rim around the bottom of the trilobite, and the softer covering of the body attached to it (Harrington, 1959). Most trilobites also had some smaller, hard plates on the bottom of their bodies at the front center. In some trilobites, they did not attach to the rest of the exoskeleton; in some, they did. They always attached to the softer covering. The most important plate was the hypostome, which covered the mouth. Hypostomes came in many shapes (Harrington, 1959). Knowing what they look like is good when you're searching for trilobites. You can find hypostomes completely separated from other trilobite parts, and they're pretty cool, too.



X-ray of a phacopid trilobite.

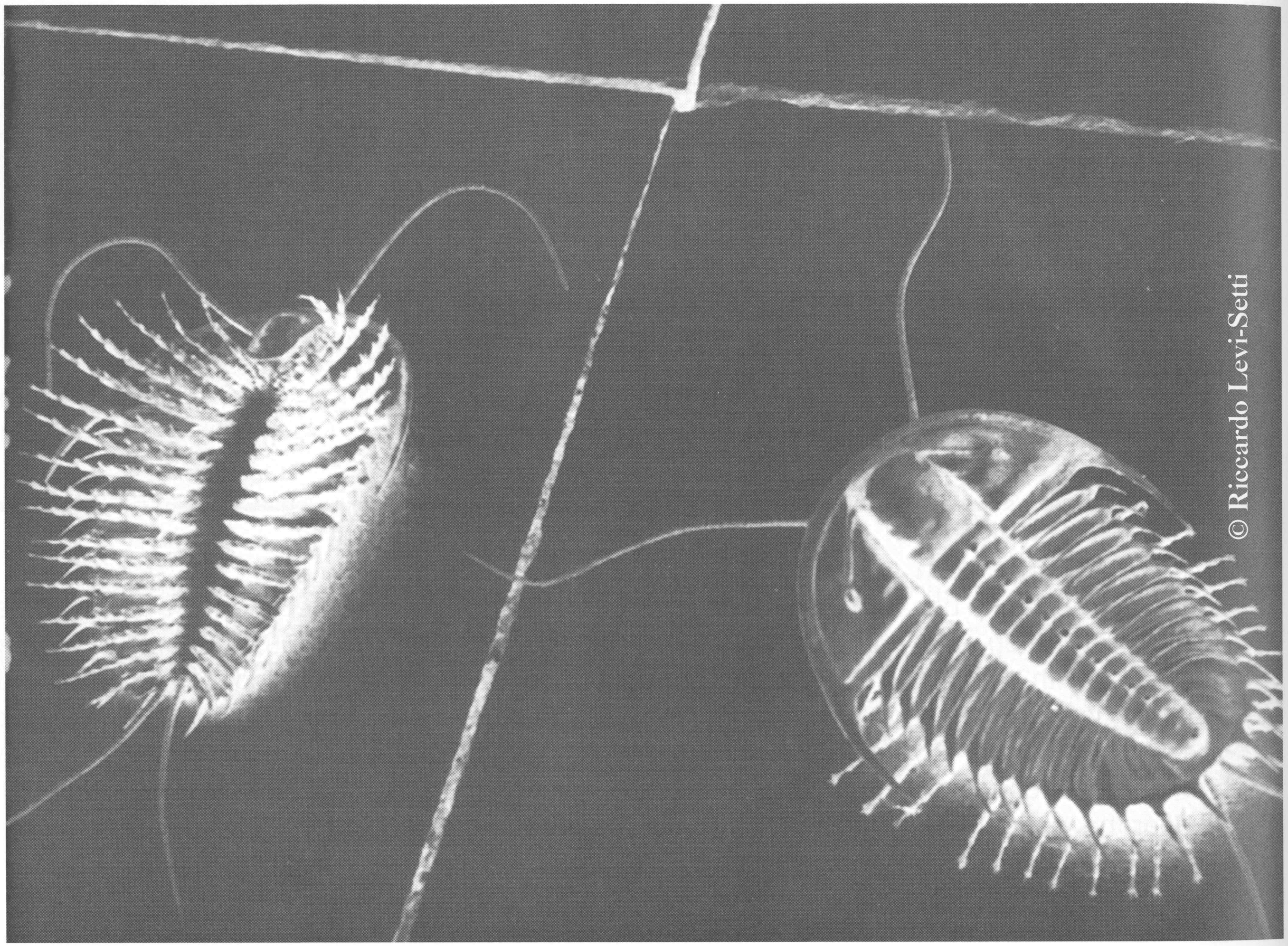
A trilobite scientist



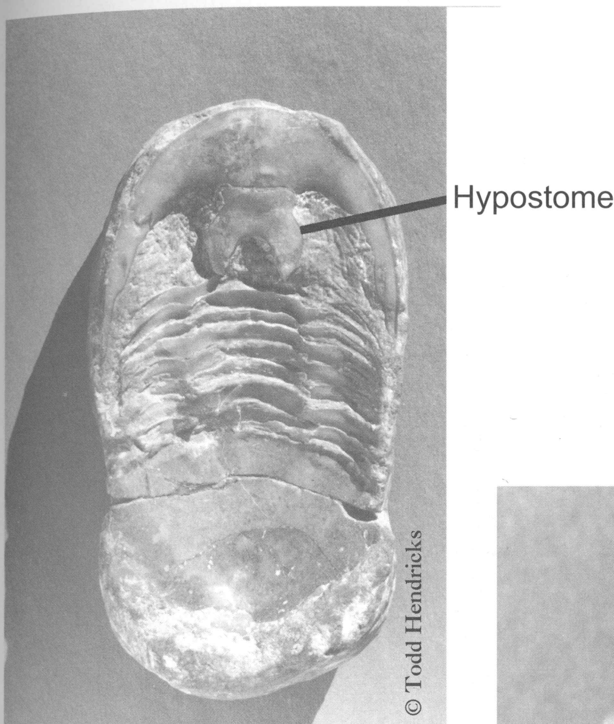
Brenda Hanke became fascinated with fossils at the age of three when she received her first dinosaur book. Growing up as a young girl in Alberta, Canada, near the Tyrell Museum of Paleontology, fueled her fascination with paleontology. Pursuing her goal of becoming a paleontologist, Brenda attended the University of Alberta. Her interests soon turned from dinosaurs to studying trilobites. She is now a Ph.D. candidate at the University of California, Riverside. Brenda's main research interests include understanding body form variation in trilobites, and the connection that variation has in evolutionary patterns within trilobites. According to Brenda, traveling all over the world to study trilobites is one of the greatest aspects of the job, and there's nothing she would rather be doing.

Most arthropods have antennae, but, like trilobites' legs, their antennae hardly ever fossilized (Levi-Setti, 1993). It's hard to know exactly how trilobite antennae looked or worked. The fossil trilobites that have been found with antennae preserved have only two antennae. The antennae were made up of jointed segments, so they were flexible, like modern arthropod antennae. They were attached to the underside of the trilobite, one on each side of the hypostome (Harrington, 1959).

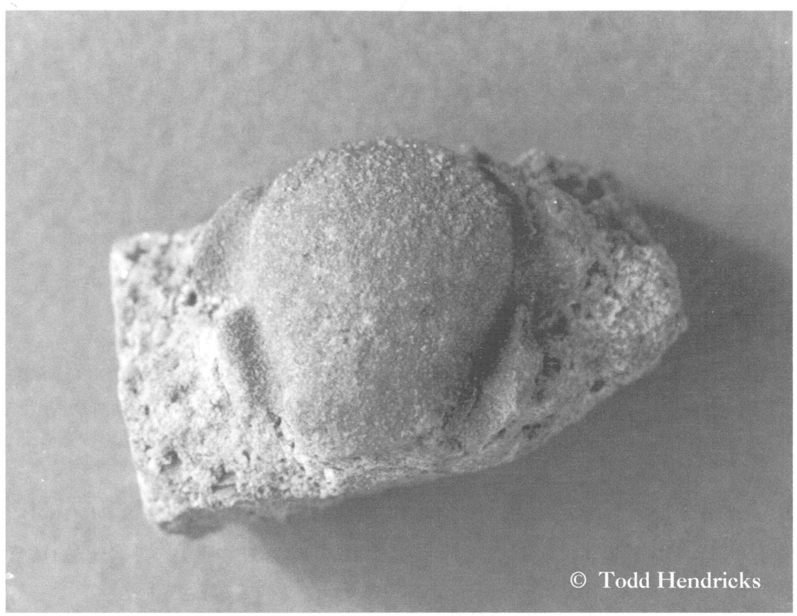
Some trilobite fossils are very, very unusual, and have a pair of tails coming off the rear. These are called cerci (SIR-sigh). Unlike spines, they're segmented and flexible, looking a lot like the antennae. So far, only one trilobite—*Olenoides serratus*—is known to have cerci (Whittington, 1997b).



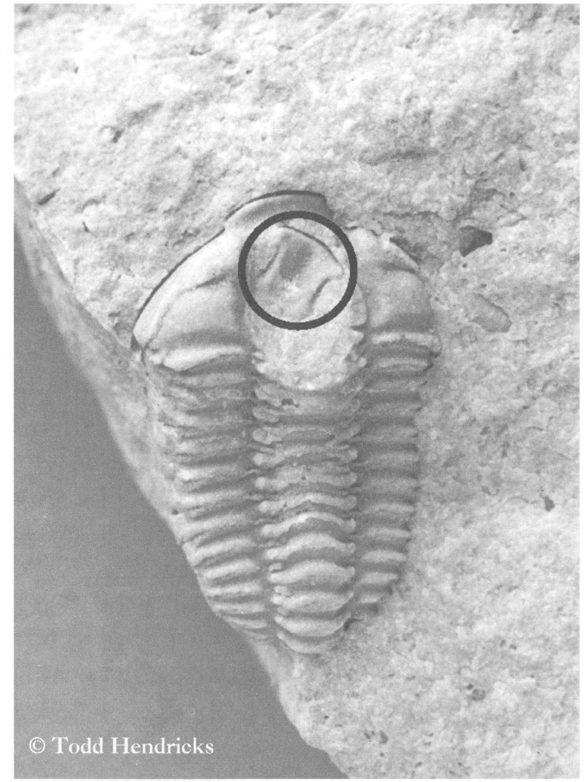
This trilobite has both antennae and cerci. Three-dimensional models show the top and bottom of a live Cambrian trilobite, *Olenoides*. They were made at the Paleontological Museum, University of Oslo. The print is a negative, showing light where dark should be. Photo from the book *Trilobites* [2nd ed.], by Riccardo Levi-Setti (1993). Reprinted with the author's permission.



Bottom side of an *Isotelus,* showing the hypostome.



Cheirurus hypostome.



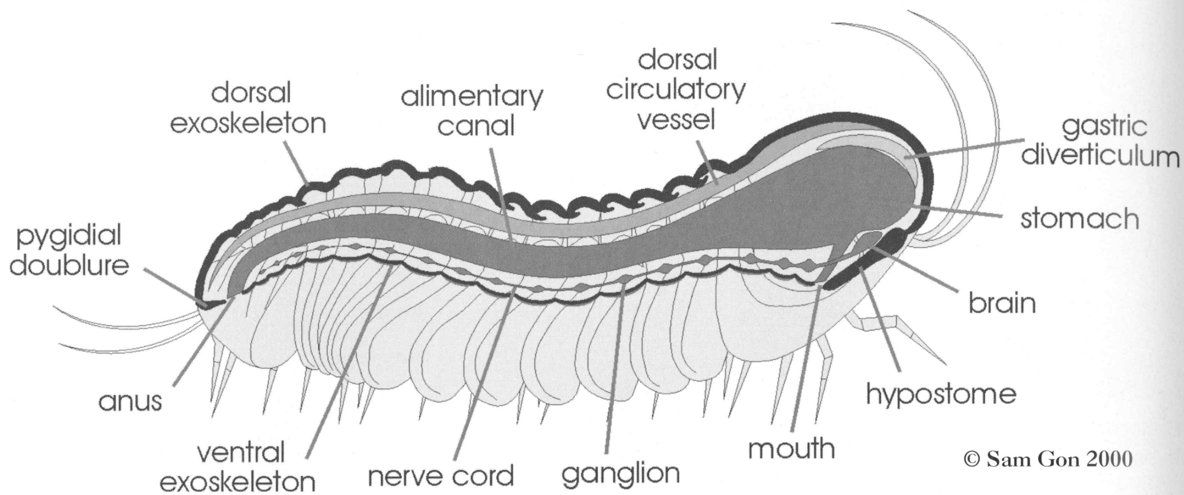
Part of the glabella is missing in this *Gravicalymene,* revealing the hypostome (circled) underneath. The hypostome has rotated clockwise slightly from the weight of sediments on top of it.

What's inside?

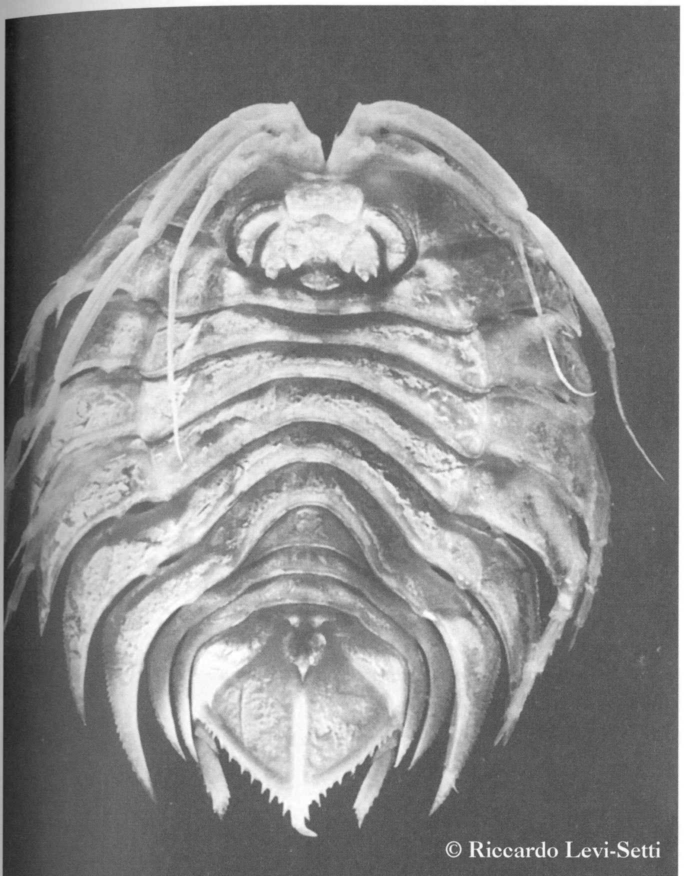
To begin with, as in many modern arthropods, the mouth was located in the cephalon area, on the bottom side of the animal. It faced backwards, toward the trilobite's tail. The mouth had no jaws or teeth. From the mouth, the trilobite's throat, or esophagus, made a U turn, and set out for the stomach. It didn't have far to go, because the stomach was also in the cephalon. If you've ever wondered what was inside a trilobite's head, the answer is DINNER! After the stomach, the intestine headed for the pygidium in a more or less straight shot, ending in an anus (Levi-Setti, 1993).

Modern arthropods have a circulatory system in which hemolymph (arthropod blood) is moved around the body by contractions of a single tube or vessel. This vessel acted like a mammal heart, but would have been much simpler than our hearts (Margulis and Schwartz, 1998). Hemolymph would have picked up oxygen from the gills and then moved it throughout the body. Carbon dioxide from the body would then have been carried to the gills to be dumped into the water.

Trilobites also had a curious branching network of canals inside their bodies called the genal caeca (SEE-ka). This extended above and to both sides of the stomach, close beneath the exoskeleton. Some caeca may have been related to digestion or, in a manner similar to organs in some living crustaceans, caeca may have been part of the trilobite's respiratory system. When a trilobite was tightly enrolled, water would not have been able to move around the gills to bring oxygen to the trilobite's hemolymph. But the caeca would have been exposed to the water, and may have been a kind of aqualung that helped the trilobite breathe even when it was tightly enrolled (Whittington, 1997b).

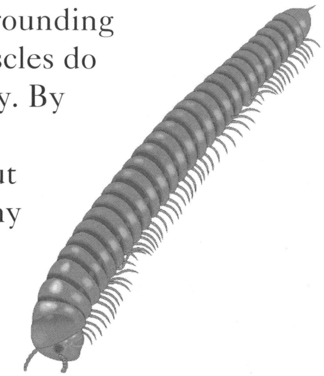


A trilobite's insides, shown from the side. "Dorsal" means the animal's top side. "Ventral" means the bottom. The "gastric diverticulum" is described at left as the "genal caeca." From Gon (2001).



A living trilobite? Alas, no, it's an isopod crustacean living in modern Antarctic seas. It looks so much like a trilobite that it has been named *Serolis trilobitoides* (Levi-Setti, 1993). Studying arthropods like these helps scientists decipher clues about fossil trilobites. Photo from the book *Trilobites* [2nd ed.], by Riccardo Levi-Setti (1993). Reprinted with the author's permission.

There had to be a complex system of muscles in the body and the limbs that trilobites used to go about their trilobite business. Surrounding the organs, the muscles attached to the exoskeleton. Human muscles do the same thing; your skeleton just happens to be inside your body. By looking at modern arthropods, and studying the muscle scars and architecture of the trilobite exoskeleton, scientists are working out the structure of trilobite muscles. Unfortunately, there aren't many clues in the fossils. X-rays have shown some mineralized trilobite muscles, and they are like those of living crustaceans (Whittington, 1997b).



If you've seen a millipede walking, you may have a hint of how a multilegged trilobite walked on the sea floor. Millipedes have segmented and jointed legs and bodies like trilobites had.

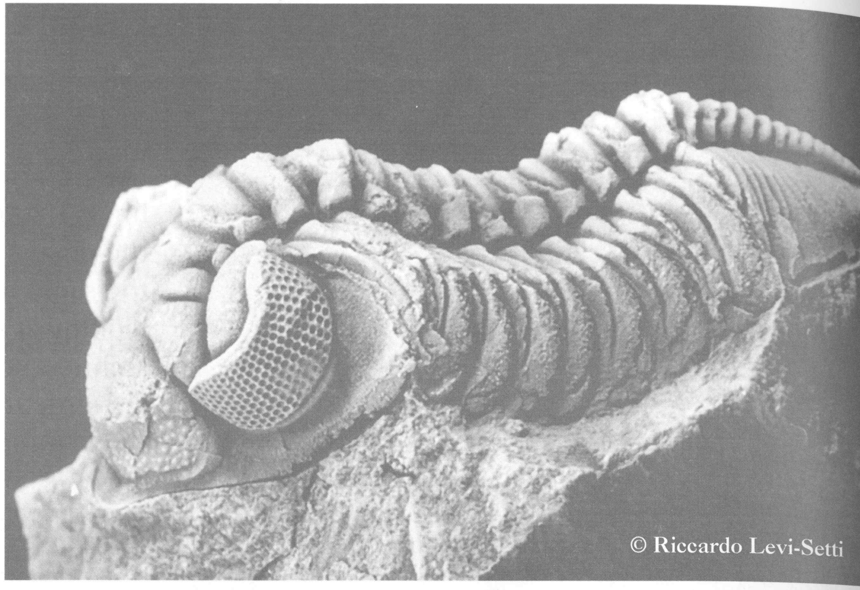
With one important exception (the eyes), we don't know much about the sensory and nervous systems in trilobites. In modern arthropods, the brain is up front, ahead of the mouth. It seems reasonable to think that trilobites were set up this way, too. Sensory input from the eyes, antennae, and other organs would have been picked up by the brain. A nerve cord (or maybe two) probably extended back from the brain to the pygidium. If the trilobite nerve cord was like the nerve cords of modern arthropods, it had nodes where nerves for each segment branched off (Gon, 2001).

As in living crustaceans, antennae, cerci, spines, and fine hairs on trilobites may have had many jobs. Chances are, some of them were used to sense the environment, especially by touch. Trilobites may have been able to sense chemicals in the water. Some unknown organs located in pits or thin parts of the exoskeleton may even have detected light (Whittington, 1997b). But, like us, some of the trilobites brought light sensing to a high art. They were intensely visual creatures.

Trilobite eyes

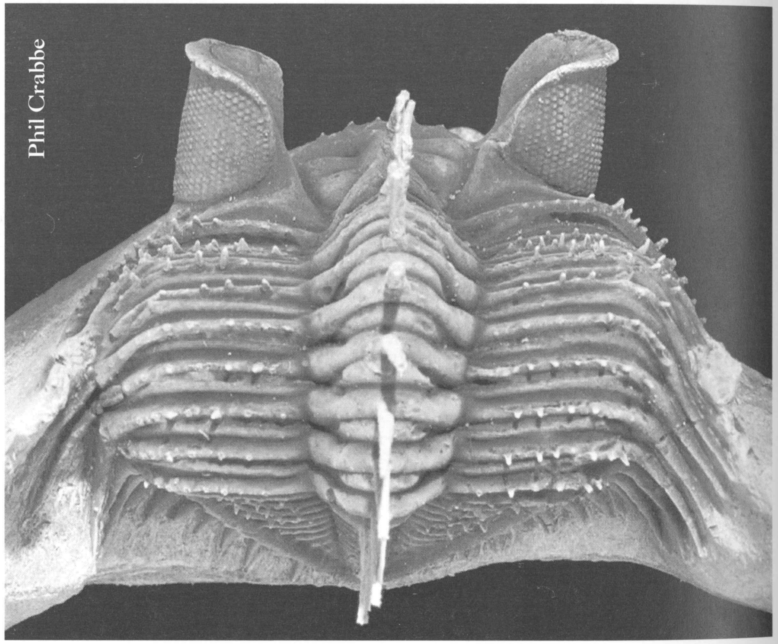
Trilobites sport the earliest known visual systems, using lenses with a network of light receptors and nerves for image processing in the brain. They were among the earliest animals with the ability to see the world around them. Because trilobite eyes are comparable to those of other arthropods, we figure that their common ancestor must have had eyes too.

We know about trilobite eyes because the lenses of their eyes were made of transparent calcite crystals. These hard minerals fossilized along with other parts of the trilobite, so we can take a good, hard look at them. The soft parts of trilobite eyes—the structures behind the lenses—are not preserved in the fossils, so scientists don't know much about them. Scientists can look at the way the crystals in the lenses are arranged and theorize how trilobite eyes worked.



Pterygometopus brongniarti. Photo from the book *Trilobites* [2nd ed.], by Riccardo Levi-Setti (1993). Reprinted with the author's permission.

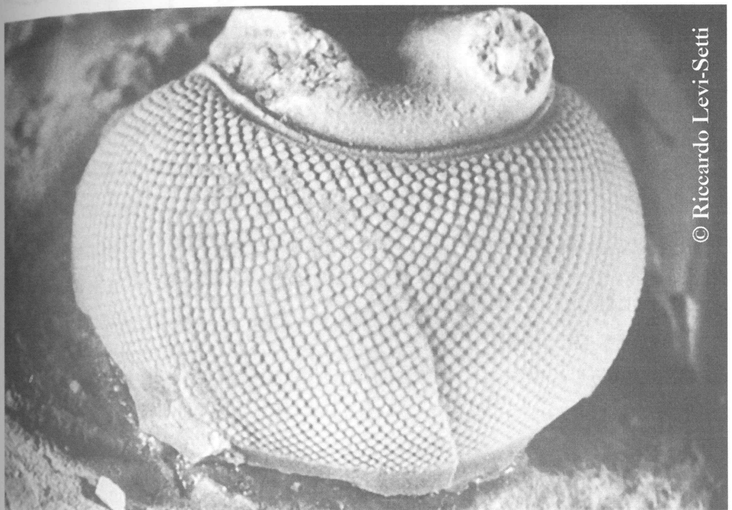
Your eyes have lenses made of soft proteins rather than hard mineral crystals. The shape of the soft lens can be changed to focus on objects very close to you, or very far away. Trilobites could not focus their eyes over as wide a range as you can, but their range of focus worked fine under water.



Erbenochile erbeni had eyes extending upward into "towers" covered with lenses. It had a 360 degree field of view. It could even see over its own back. The top of the eyes extended out over the lenses, cutting out glare from above. This trilobite could see even small movements at a distance over the sea floor. Reprinted with permission from Fortey, R., and Chatterton, B., 2003, A Devonian trilobite with an eyeshade: Science, v. 301, p. 1689. Copyright 2003 American Association for the Advancement of Science.

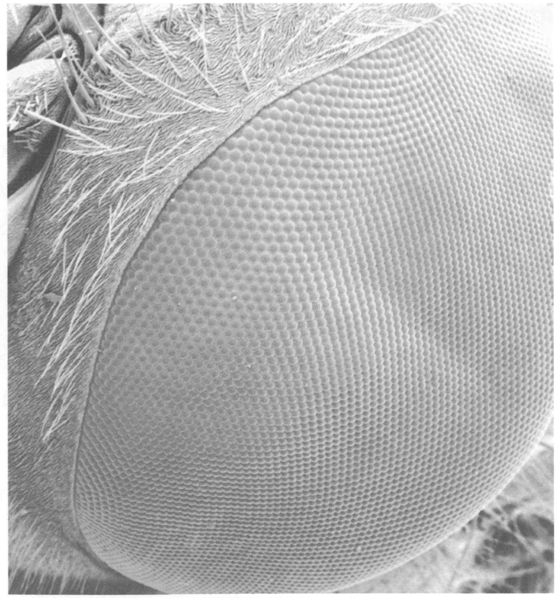
Holochroal eyes

Take a look at a fly's eye (some magnification helps). You will notice a pattern of many lenses, making it a compound eye. Some insects have as many as 15,000 separate lenses. Each lens points in a slightly different direction to gather light from its own tiny section of the world. The light forms an image of that section on light receptors that connect to the brain with nerves. The insect sees the world not only with its eyes, but also uses its brain to process the image that is transmitted from the light receptors.



Holochroal eye of *Scutellum.* Photo from the book *Trilobites* [2nd ed.], by Riccardo Levi-Setti (1993). Reprinted with the author's permission.

The earliest trilobites had compound, also called holochroal, eyes. Did many trilobites see the same way insects with compound eyes do? It's likely, because every known detail of trilobite holochroal lenses looks so much like insect compound eyes. They even had a similar range of numbers of lenses—100 to 15,000.

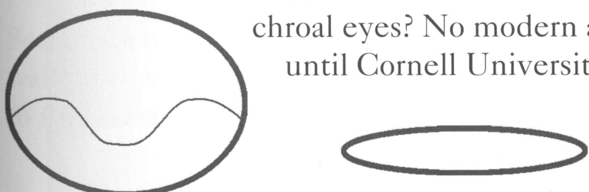


A fly's eye. Ric Bessin

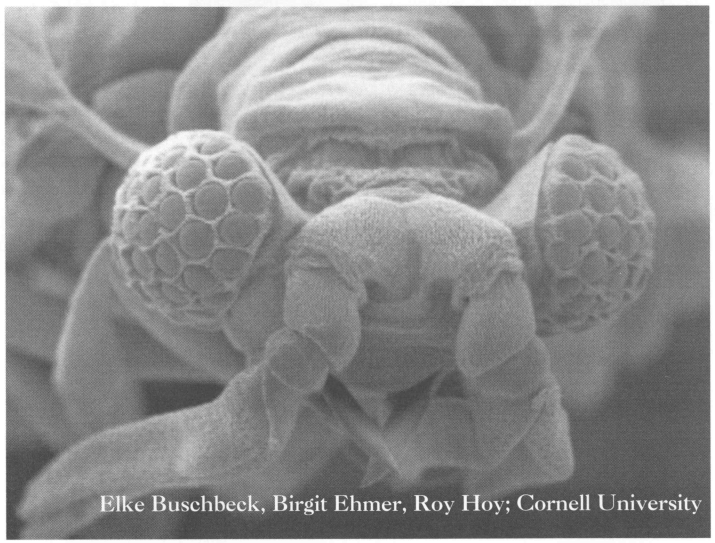
Schizochroal eyes

Holochroal eyes worked well for many trilobites for millions of years, but these types of lenses probably did not focus light into a very sharp image. One later group of trilobites, the phacopids, developed a two-part lens with a special shape in the center. This would have corrected the focus of the front part of the lens. It was as if nature had given the trilobites a good pair of eyeglasses. They could probably see their surroundings in sharp detail. Schizochroal (skit-so-CROW-al) eyes, as they are known, have fewer and bigger lenses than holochroal eyes.

Can modern animals such as insects give us clues about schizochroal eyes? No modern animals with schizochroal eyes were known until Cornell University scientists Elke Buschbeck, Birgit Ehmer, and Ron Hoy looked carefully at the eyes of a tiny insect. *Xenos peckii* has eyes that are very different from the usual insect compound eyes. Their lenses



(Left): Shape of schizochroal eye lens. (Right): Shape of simple lens found in holochroal eyes.



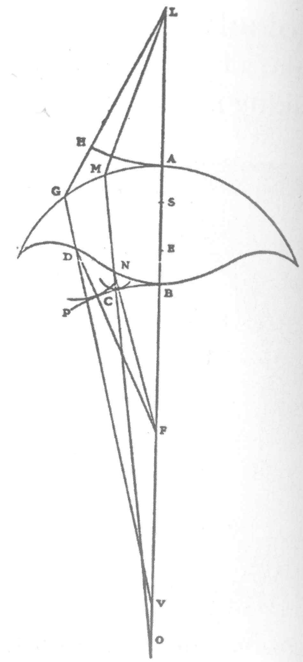
Xenos peckii. Although it has solved a visual problem the same way, *Xenos* is not directly related to the trilobite. Reprinted with permission from "Chunk Versus Point Sampling: Visual Imaging in a Small Insect." Copyright 1999, AAAS.

are very large, and there are not many of them—about 50 in each eye. The scientists were surprised to find that the insect's lenses were schizochroal. They look very much like the schizochroal lenses of the trilobites, with the same center shape for sharp focus. Each lens has about 100 light receptors.

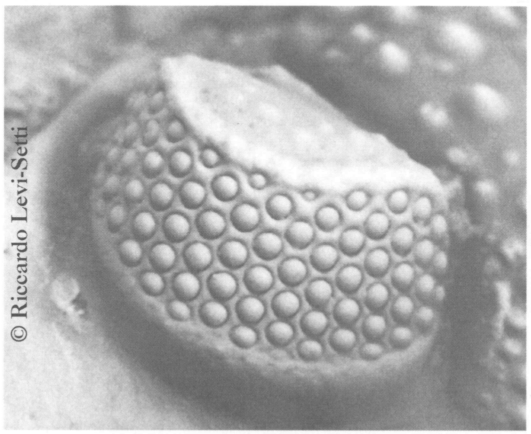
The compound eyes of most insects, such as flies, have hundreds of lenses, but each lens works with only a few light receptors. A fly sees the world as many, many small points of light, whereas *Xenos* is looking at a few large chunks of light. The chunk type of eye is called a composite or aggregate eye. Since it gathers more light and has more light receptors, it focuses a sharper image than a compound eye does. *Xenos* can actually see better than a fly.

When the scientists looked closely at the whole visual system in *Xenos*, they found that a whopping three-fourths of the insect's brain is used to process the chunks of visual information (Buschbeck and others, 1999)! Did trilobites with schizochroal eyes see in this way? Although we can't know for sure, it seems quite likely.

Some trilobites had no eyes at all. They lived on or in the bottom mud and used their limbs and antennae to move around and find food. A good sense of touch, and perhaps chemical sensors, were all they needed. Many modern arthropods lack eyes.



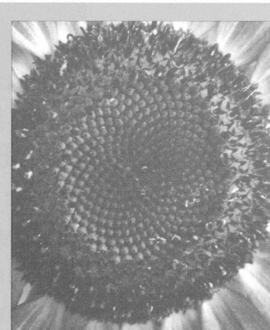
People didn't figure out the schizochroal type of lens, much less make one, until 1637—long before anyone knew that some trilobites had them. Christian Huygens, the astronomer and telescope maker, drew this diagram of a schizochroal lens in 1690.



Schizochroal *Phacops* eye. Photo from the book *Trilobites* [2nd ed.], by Riccardo Levi-Setti (1993). Reprinted with the author's permission.

Schizochroal *Odontochile* eye. Photo from the book *Trilobites* [2nd ed.], by Riccardo Levi-Setti (1993). Reprinted with the author's permission.

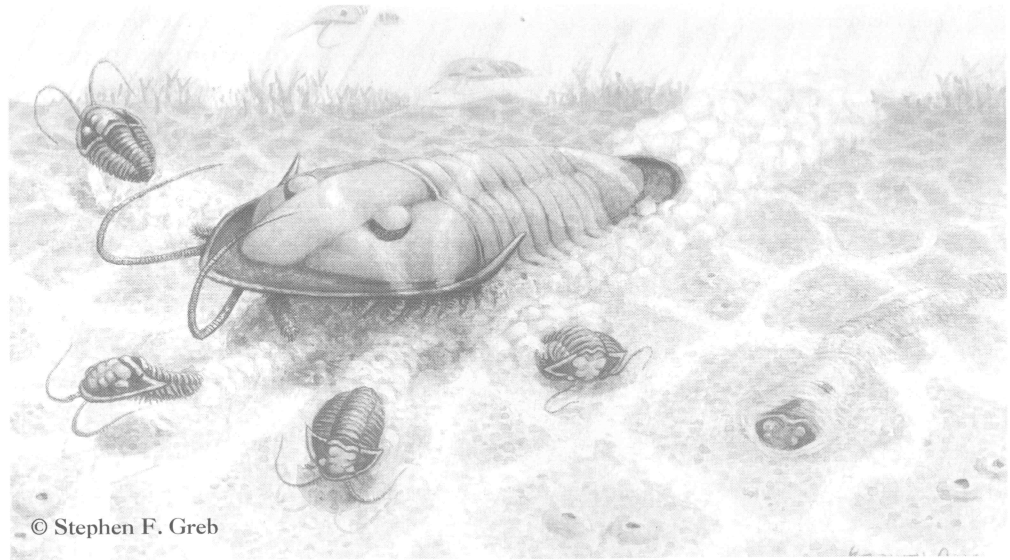
© Judy Lundquist



The arrangement of the lenses in insects' and trilobites' eyes, if you look very closely, is hexagonal—like a honeycomb. If you look at the whole eye, you will see a pattern of spirals. When some things with circular form grow, they take this pattern. It can be seen in many plants, such as this sunflower.

Trilobite lives

How do paleontologists track what happened as far back as 540 million years ago, when the trilobites got their start? Comparing trilobites with living crustaceans can be useful. But scientists have to be careful. Although trilobites were perhaps similar to crustaceans, they were not crustaceans. Living crustaceans can be observed in detail, and can tell us about what might have been *possible* for trilobites, but not exactly what they were doing.



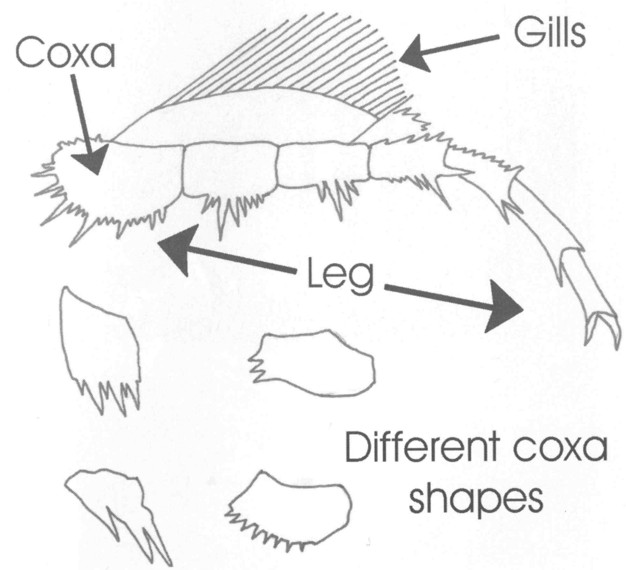
Isotelus and *Flexicalymene* go about trilobite business.

Knowing where a particular kind of trilobite lived can help with figuring out its lifestyle. If you know which kinds of rocks were formed in which environments, you can say that a particular trilobite, found in a particular kind of rock, lived on a coral reef, or in mud close to shore, or farther offshore. Clues to environment can also come from other fossils found with the trilobites. Were they reef animals, or did they swim in deeper water? Did they burrow in a mud bottom (Whittington, 1997a)?

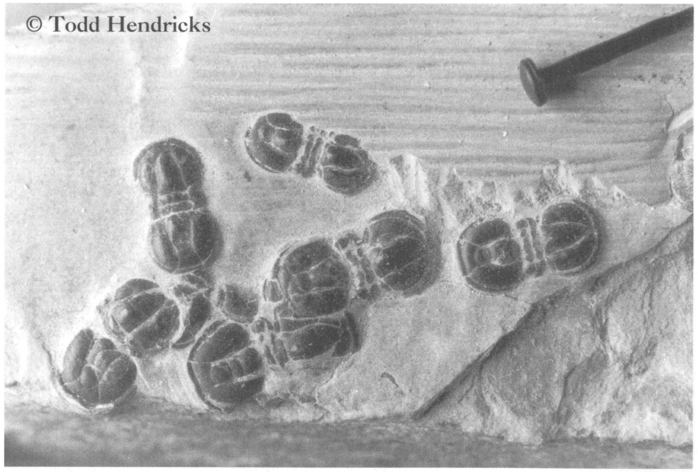
Making a living

Eating was perhaps the most important order of trilobite business (after all, it's pretty high on our lists). Trilobites had a set of prickly legs that would have been good at grabbing—the more legs, the better. The trilobite legs that have been found fossilized have large, strong, and spiny segments, called coxae (COX-ee), at the tops of the legs. Any morsels grabbed would have been squeezed and shredded to bits between the coxae. The bits would then have been passed forward in a sort of conveyor-belt fashion, to be caught in the hypostome. The backward-facing mouth could then suck in the goodies (Whittington, 1997a).

The size and shape of different types of legs offer clues to their capabilities and uses. Some trilobites had legs that were all long enough to have supported the whole body as they walked on the sea floor. Walking, perhaps digging or plowing, must have been a common way to find food.



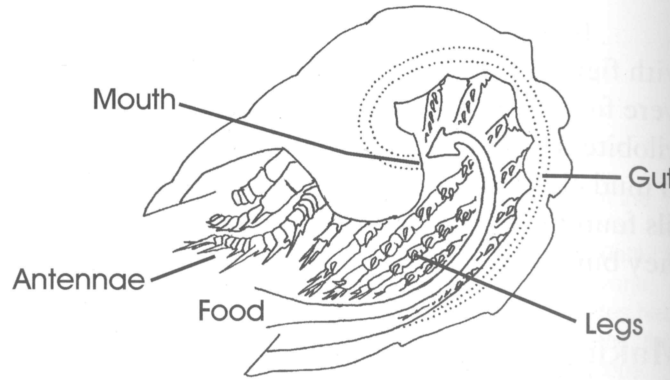
Not only did trilobites arrange their stomachs in their heads, they had their mouth parts on their legs. Modified from Whittington (1980, Fig. 8) by permission of the Palaeontological Society.



The pin head at the upper right shows that *Agnostus* was very small.

Agnostus is an example of a trilobite that had long legs in the middle and short ones under its head and tail. If it had walked, the short legs would not have reached the bottom! But when *Agnostus* was partly enrolled, the legs would have made a neat and tidy set of oars. It seems likely that *Agnostus* drifted and swam near the bottom, sweeping in food particles with its antennae and legs (Whittington, 1997a).

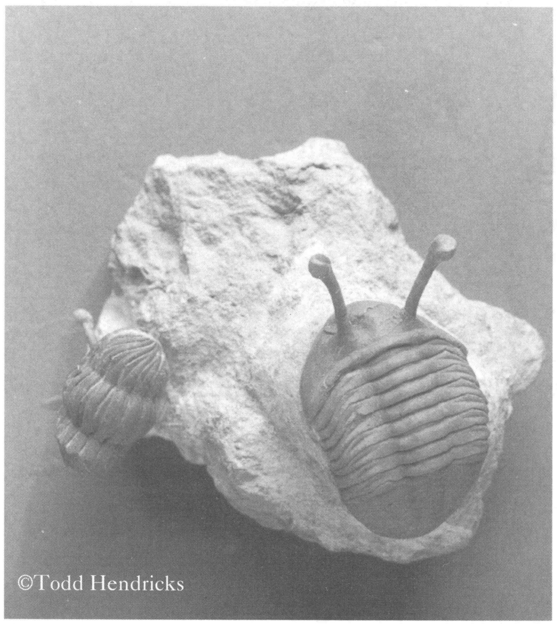
Trilobites with big heads could have had big stomachs for processing large pieces of prey. Tiny bits would have been taken in by filter or particle feeders. Having the hypostome firmly attached to the doublure of the exoskeleton would have made processing big chunks of prey easier, so chances are, trilobites with this arrangement were predators. Hypostomes that were not attached to the rest of the exoskelton could have moved, at least a bit. This might indicate that their owners were scavenging on small organic particles found on the sea floor, or perhaps even grazing on algae, rather than being active predators (Fortey and Owens, 1999).



Even filter-feeding trilobites such as *Agnostus* used their legs to pass the particles of food to their mouths (Whittington, 1997a). Adapted from *Fossils & Strata,* www.tandf.no/fossils, by K. Muller and D. Walossek, 1987, v. 19, p. 1–124. By permission of Taylor & Francis AS.

Some trilobites such as *Elrathia* are found in huge numbers. Such numbers may indicate an herbivorous rather than predatory lifestyle. They may have been prey for bigger animals (Fortey and Owens, 1999). Herds of plant eaters such as modern zebra vastly outnumber their predators, such as lions.

Some trilobites had a big head; that is, the cephalon was far deeper than the thorax and pygidium. That they would have walked on the sea bottom seems unlikely, unless they had stilts for legs. Did they live in a burrow with the cephalon sticking out (Bergstrom, 1973)? Such burrows have never been found (Whittington, 1997a), but it may have been a great way to ambush breakfast!



Some trilobites such as *Neoasaphus* could have hidden with their eyes just above the surface of the mud. Another great ambush strategy, or just a way to watch out for predators from above? We don't know for sure.

Some trilobites had huge eyes. They could see all the way around and behind their narrow bodies, as well as below. The pygidium was small, and the cephalon was shaped to move easily through water. This tells us that they swam for their snacks (Levi-Setti, 1993). The more streamlined swimming trilobites could have been fast, and possibly were predators (Fortey, 1974).

Trilobites! The Movie*

By K.C. Gass

Why don't they make a film
Of resurrected trilobites?
I don't know what they're
  waiting for.
This tale should be in lights.

It never has been done
  before.
Why can't they do it now?
It has great possibilities
And I could tell them how.

The film would have no
  dinosaurs.
T. rex is getting old.
No aliens or hungry
  sharks—
Those stories have been
  told.

This movie would be
  different.
Its villains are quite small.
They look as though they
  couldn't
Bother anything at all.

The first one was intriguing,
Which came as no surprise.
They watched it live and eat
  and grow
Before their very eyes.

Genetic engineering
Had brought the beast to life.
And when it was two inches
  long,
They put it to the knife.

The first thing that they
  noticed
Was how hard it was to kill.
They couldn't understand just
  why
And maybe never will.

They dissected its cephalon,
Its thorax and its tail.
And when a liquid squirted
  out
Their hearts began to fail.

This fluid was corrosive—
Much more so than the rest.
It ate right through a thick lab
  coat
And burned the worker's
  chest.

The movie carries on with
Many ominous events.
The problems are peculiar
And they soon become
  intense.

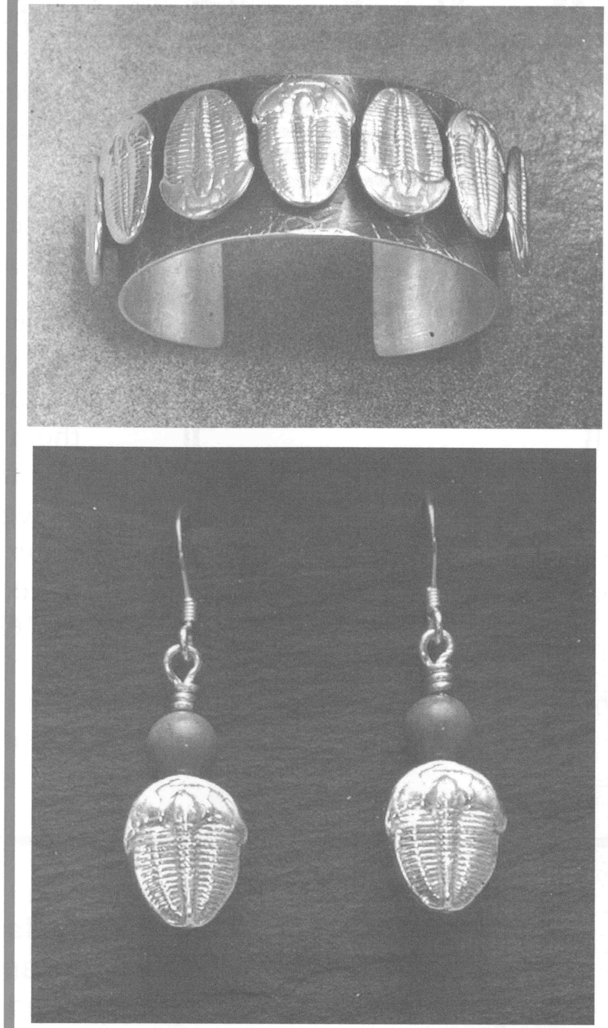
For example, it is shown
That their adaptability
Is developed far beyond what
All past research could
  foresee.

They're amazingly prolific,
Storing eggs inside their
  cheeks.
A breeding pair can generate
Five million in nine weeks!

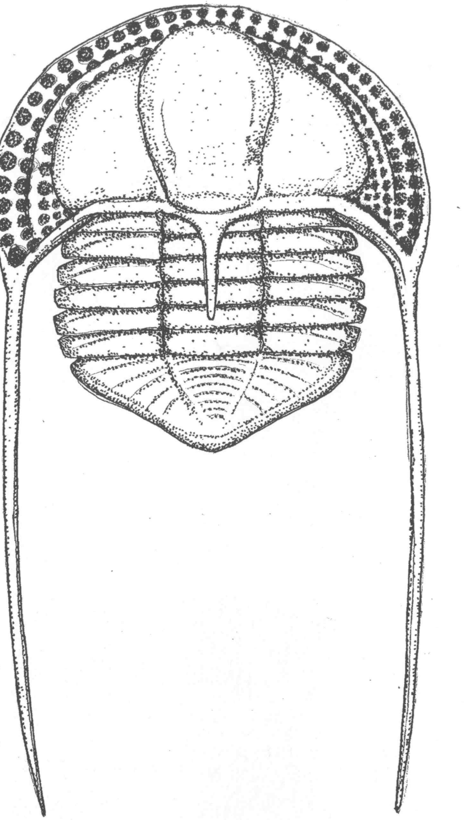
You probably have guessed
  by now,
Things soon get out of hand.
The trilobites are
  everywhere—
In seas and lakes and sand.

They're immune to our
  diseases
But infect us with their own.
See! A movie based on
  trilobites
Could chill you to the bone!

*From Gass (2000). Reprinted with permission of Specialized Quality Publications.



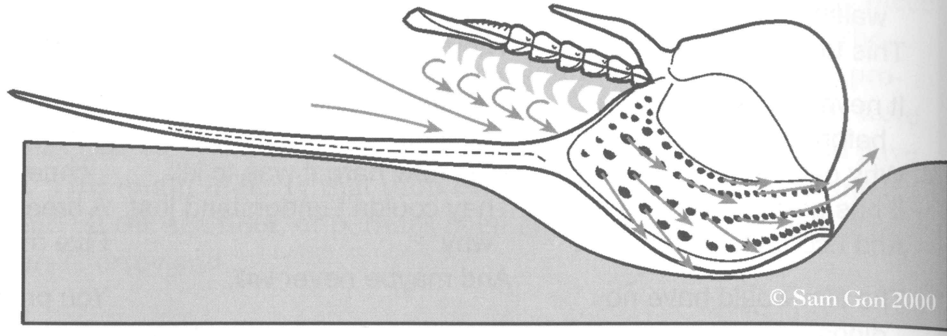
Cast silver trilobite jewelry by Dave Burchett. Rubber molds were made from *Elrathia* trilobites, for casting the silver jewelry.



Cryptolithus.

Trilobites such as *Cryptolithus* had a pitted fringe around the cephalon, like a cowcatcher on a train. They could have used it to plow through bottom mud. They could have rested partly buried on the bottom. Since *Cryptolithus* was blind, the fringe may have helped the trilobite sense its surroundings (Campbell, 1975). *Cryptolithus* fossils are found in Kentucky.

Here's another idea about the "cowcatcher."



Cryptolithus as colander.

The pits in the fringe are actually holes that go all the way through from top to bottom. You might think of them as a strainer. The trilobite may have paddled with its legs, moving the water (shown by arrows) from the rear toward the front. Food particles in the water would have been grabbed by the legs and stuffed in the mouth. The water then would have exited through the holes in the fringe. So it might not have been a cowcatcher, but a colander (Fortey and Owens, 1999).

A trilobite scientist

Nigel Hughes grew up going on family hikes and became interested in natural history when he was about eight. Geology and fossils became a passion when he was 11, and at age 18 he was lucky enough to visit India. In college he majored in geology, but also studied biology. He has since combined his interests in hiking, fossils, and India by studying Himalayan trilobites of Cambrian age. He's using these fossils to tell us about ancient movements of the continents and the building of the Himalayas. He's also interested in the evolution of trilobite growth, and this work has resulted in research trips to the Czech Republic. He considers it a privilege to love his job, and is looking forward to sharing his future travels in search of trilobites with his children.

Judging by the rocks in which they're found, trilobites of the olenid family lived on sea bottoms that were almost without oxygen, but had a lot of sulfur. Then as now, some bacteria could live on the sulfur in such places. We know that some modern animals in high-sulfur environments, including some shrimps, feed on the sulfur bacteria. Dr. Richard Fortey (2000a) has suggested that the olenid trilobites, like the shrimps, "grew" a "garden" of sulfur bacteria on their gills. Dinner on the spot!

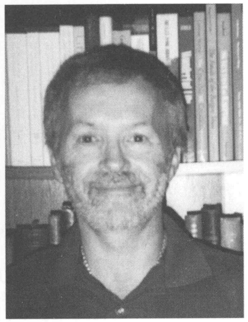
Dr. Fortey offers some evidence in support of his idea:

- Many olenids had a lot of very wide segments, providing abundant gill surface as living space for the bacteria.
- In some of the olenids, the hypostomes were so small that it looks as if they could not eat in the normal way. They may have absorbed nutrients from the bacteria through their gills.
- In their low-oxygen environment, olenids did not run into many predators. They had no need for a thick exoskeleton for protection, and indeed, it is very thin.

As usual with trilobites, there are a lot of unknowns. More information from the fossils could support this idea, or could kill it.

A trilobite scientist

I owe much of my love of life to trilobites, and I owe much of my love of trilobites to the many family members and friends who have encouraged my interests from childhood and on. Certain events in my life stand out: my sister showing me a picture of a dinosaur in her biology book; bringing my first trilobite to the local museum to be identified by a very helpful paleontologist; being told by my mother to take all the science and math I could in school to prepare me for being a paleontologist; being told by my wife to pursue my passion for trilobites, even though I had chosen not to get a Ph.D.; and finding that paleontologists are some of the most helpful, unselfish people around. All of this resulted in my assembling a large collection of fossils, discovering new kinds of trilobites, collaborating with many of the leading trilobite authorities, publishing articles in international scientific journals, having my work referred to in the *Treatise on Invertebrate Paleontology* and many other sources, and having fun every step of the way. Those segmented sea beasts are pretty cool, and they're in some pretty good company.

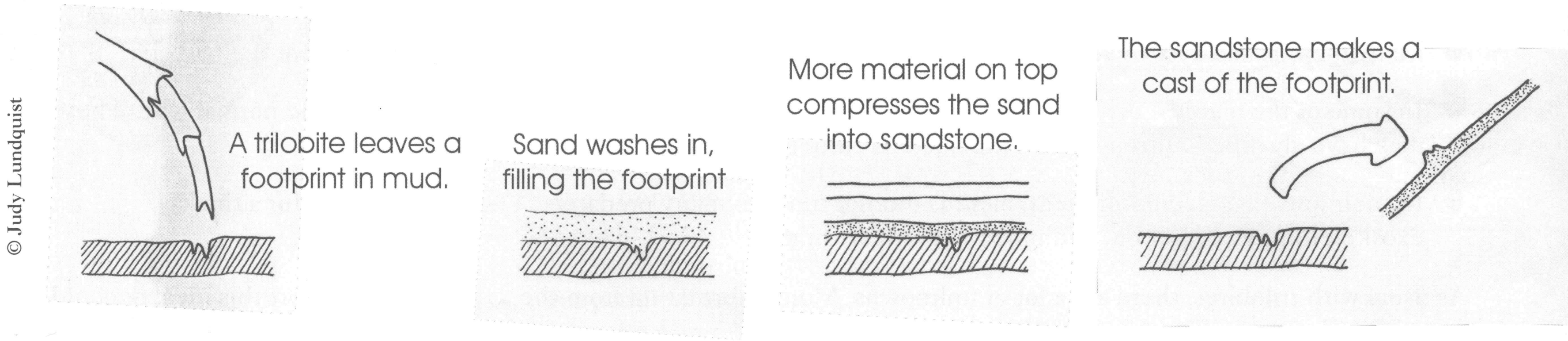


Karly Gass

—Chris Gass

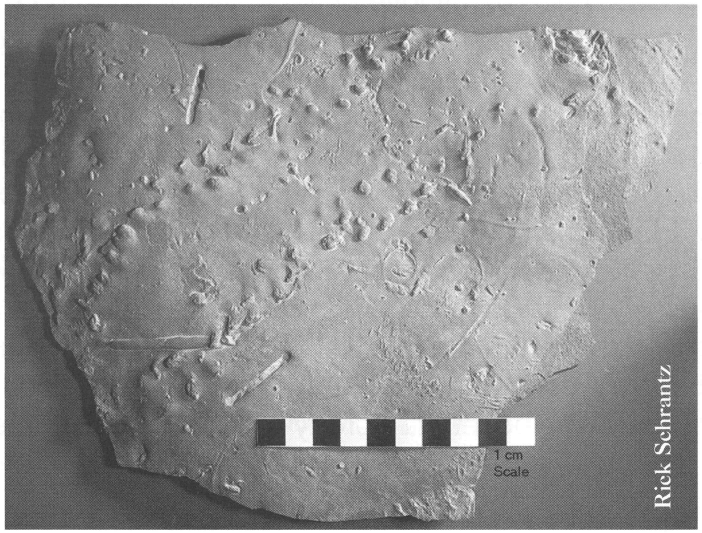
Tracking trilobites

Footprints and trackways (a series of footprints that shows a path) are called trace fossils. Trace fossil clues come closest to showing us just what trilobites were up to—*if* we're sure that trilobites made them. Imagine a trilobite searching for food. It walks over a soft, thin layer of sand and mud recently washed in over the harder mud bottom. It's looking for bits of soft-bodied animals that may have washed in with the sand, or maybe even live prey. If its feet sink through to the mud bottom, they may leave tracks, just as the feet of modern bottom-dwelling arthropods sometimes do. When the trilobite raises its feet, the sandy layer washes into the footprints. These footprints may be preserved as fossils.



A way to make fossil footprints.

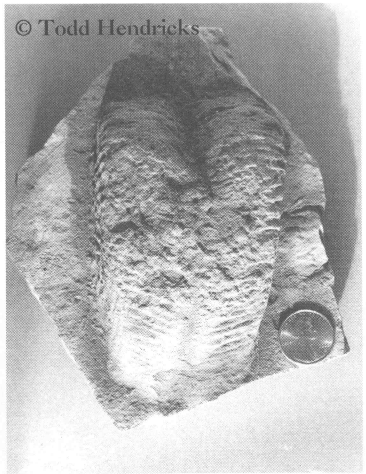
The trace fossil *Cruziana* could have been made by a trilobite. It's found in the right places and right age rocks. It is of similar size to the size of trilobites known to have been living at the time. There are many traces on this specimen. This could mean there were many trilobites, one trilobite that looped back and forth along the bottom, or possibly another type of arthropod track maker.

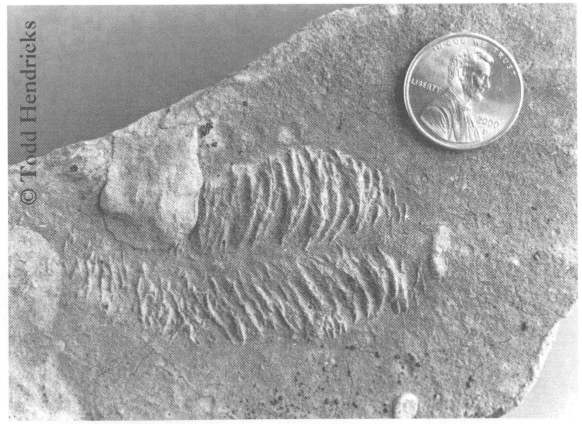


Cruziana specimen.

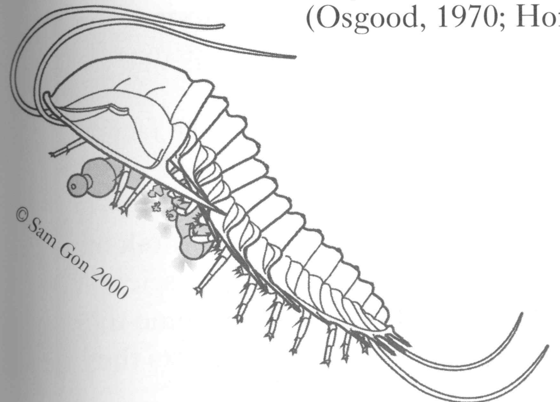
These trace fossils, called *Rusophycus,* were made by trilobites digging straight down into the muddy bottom. The holes they left were filled in by sand. That's why the tracks sometimes look upside down. They're actually sand casts of the tracks. The trilobite dug into the mud layer from side to side with its legs. This left a set of scratch marks on each side. The marks are wider toward one end, narrowing back toward the other. This matches the body of the trilobite, and the size of its legs (Whittington, 1997a).

Scientists are certain that these types of tracks were made by trilobites because trilobite fossils are sometimes found in the holes at the end of the trails. One *Rusophycus* was found with a complete exoskeleton of the trilobite *Flexicalymene meeki* right on top (Osgood, 1970). Other trace fossils show imprints of the bottom edges of the trilobite, as well as its footmarks (Osgood, 1970; Hofmann, 1979).

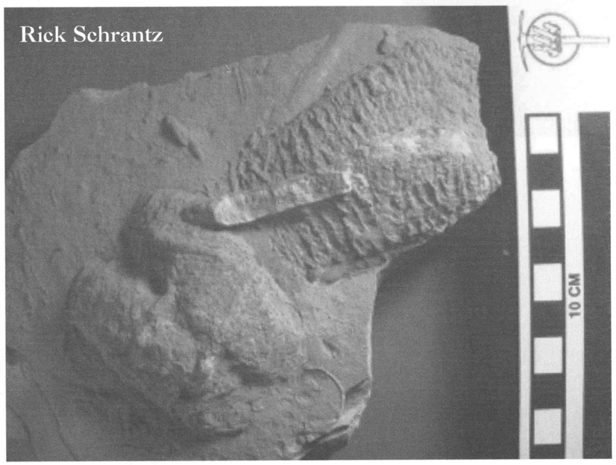




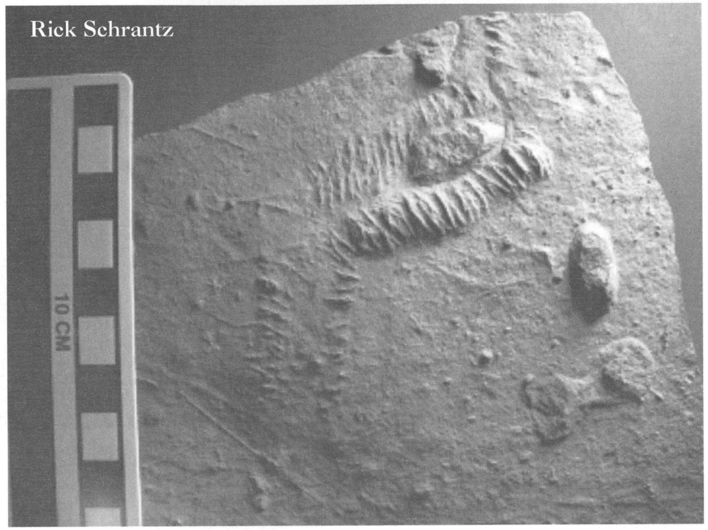
Rusophycus fossils.



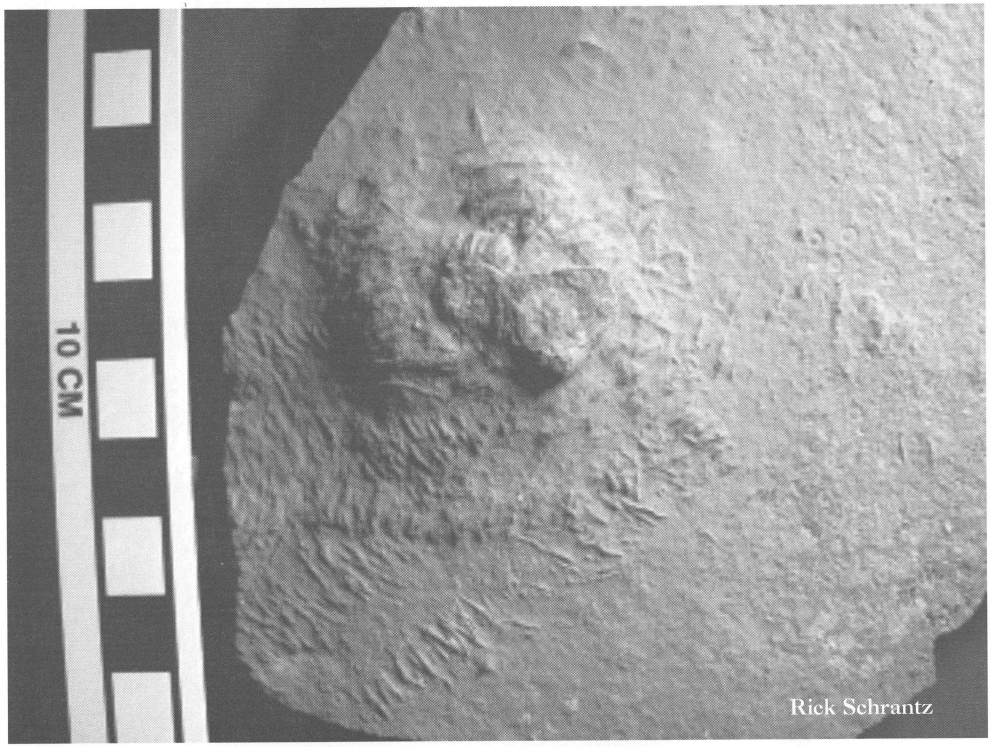
Stars of the trace fossil movie "Trilobite Snatches Worm!" From Gon (2001).



Some *Rusophycus* burrows occur above worm burrows, suggesting that the trilobites were hunting the worms.



Shallow dig marks seem to turn toward a worm burrow, then get deeper.



A curious *Rusophycus*.

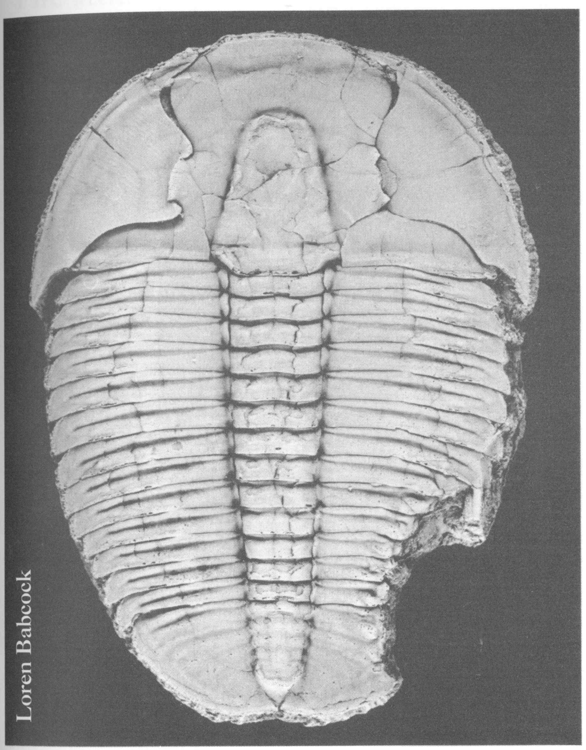
Can you interpret this trace fossil? What do you think happened? Imagination is an important tool of science, but it must always account for the facts. You can make many good guesses, but scientists need to go beyond guessing, even good guessing. Scientists use imagination to make hypotheses. A hypothesis is still a guess, but with a difference. A hypothesis has two main parts:

- It must be completely consistent with all known facts.
- It must be an idea that can be tested.

Testing ideas about fossils can be tough. Can you think of ways to test your ideas about this trilobite fossil? One way scientists test hypotheses of fossil trilobite trackways is to examine the behaviors of modern arthropods and see what types of tracks they leave behind.

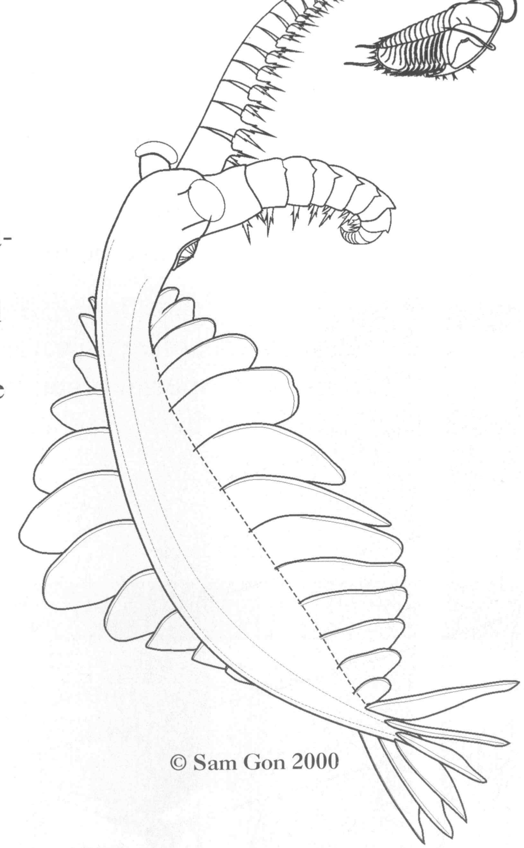
Trilobites as dinner

Trilobites not only ate, they were eaten. They shared their seas with some pretty dangerous predators who were much larger than they were. The unwary, or maybe just unlucky, would have been snacks for cephalopods (squid-like animals with a long shell), sea scorpions called eurypterids, and in the Cambrian Period, *Anomalocaris*. *Anomalocaris* was the largest arthropod of the Early Cambrian seas. In the Devonian Period and later, fish may also have eaten trilobites (Gon, 2001). Some trilobite fossils show healed injuries, which suggest they got away by the skin of their hypostomes (Whittington, 1992).



The one that got away. *Elrathia* with a healed bite mark. The chunk taken out matches quite well with the mouth parts of *Anomalocaris,* found in the same rocks (Babcock, 1993).

Still, trilobites survived for millions of years, so they must have had good defenses. They were probably good at hiding, as many modern arthropods are. Besides the hard carapace, many of them had spines that would have made them unattractive to eat. Most of them also had the trick of enrolling so that the hard exoskeleton would cover the whole body. This may have made them too crunchy to eat (Levi-Setti, 1993). Unfortunately, unlike earlier fish that did not have jaws, Devonian fish could have opened their mouths and swallowed enrolled trilobites whole. Even so, some of the spinier trilobites must have been quite a prickly bite.



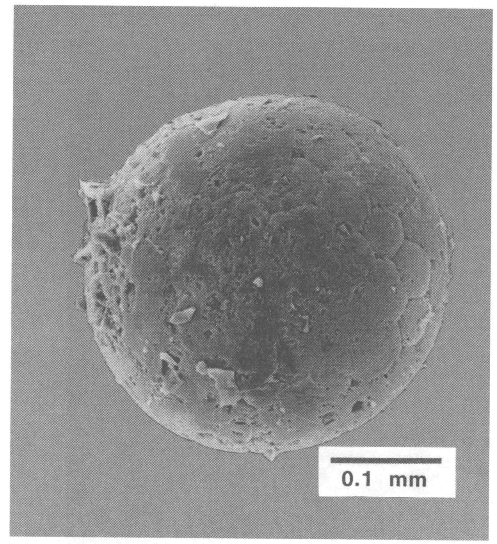
Anomalocaris closes in on *Olenoides*. From Gon (2001).

Trilobite babies and how they grew

Our ideas about how trilobites reproduced are educated guesses. Arthropods today come in male and female, so it's not a bad guess that trilobites did too. How the two sexes actually got together is murky. Quite a few rocks have large numbers of fossil trilobites close together, at one level. Sometimes the trilobites are almost the same size. In at least one case, there may be two types within the same species. This points toward the idea that they may have been gathering together at a certain age to molt and mate (Speyer and Brett, 1985). Some living marine arthropods cluster in just this way.

Modern arthropods that live in water may lay their eggs in the water, or carry them around until they hatch, or even carry the young after they hatch. Some have special brood pouches built for carrying the eggs or developing young until they can fend for themselves. The many kinds of trilobites may have used any of these strategies, and maybe some that haven't even occurred to us.

Stamps from the Czech Republic honor the trilobite pioneer Joachim Barrande.



A trilobite egg? In one instance, when paleontologists thought they might have found trilobite eggs, they published the idea with some uncertainty. Reprinted with permission from Zhang, X.-G., and Pratt, B., 1994, Middle Cambrian arthropod embryos with blastomeres: Science, v. 266, p. 637–639. Copyright 1994 American Association for the Advancement of Science.

The strange case of the bubbleheads

Several kinds of trilobites have a large lump on the front of the cephalon. Paleontologists didn't know what to make of these "bubbleheads." Sometimes, two forms of trilobite fossils are found at the same site—one has the bubble and one doesn't. Since they aren't different in other ways, they would have been closely related. Because there was no way of telling what the bubble was, in the past they were usually named as two species.

A bubblehead breakthrough came to paleontologist Richard Fortey in a fish market in Thailand. He saw horseshoe crabs for sale. The attraction is not the meat (they don't have much), but the eggs. Female horseshoe crabs carry their eggs inside their heads, underneath the front end of the carapace. Horseshoe crabs are related to trilobites. Bingo! Dr. Fortey, in his imagination, could see a trilobite mom carrying her eggs inside a bubble on the front of her head (Fortey and Hughes, 1998).

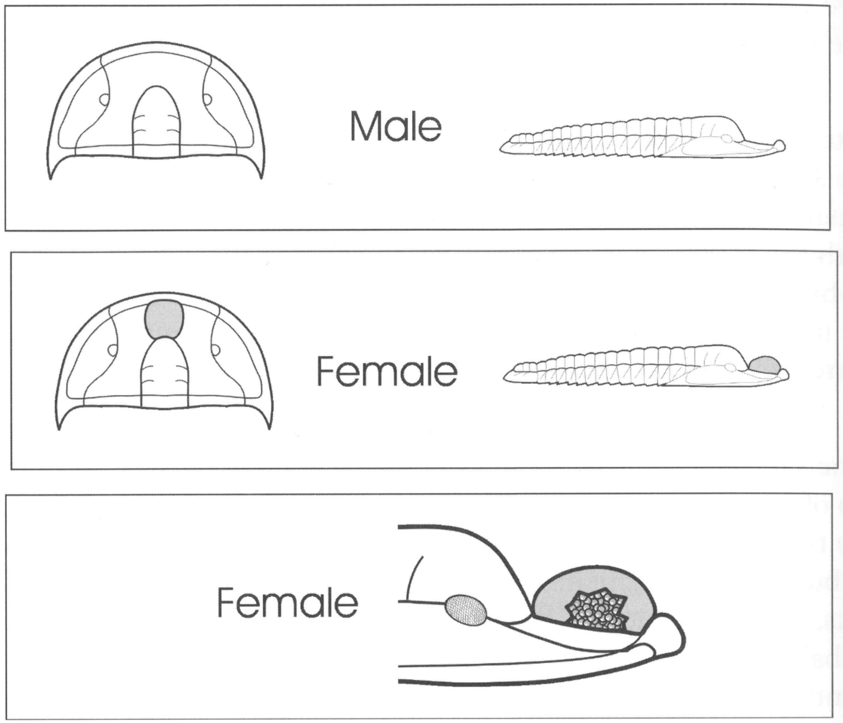
If the bubbleheads and nonbubbleheads are female and male of the same species, the bubbles might be brood pouches. After this leap of imagination, Dr. Fortey teamed up with Dr. Nigel Hughes. The two paleontologists looked very carefully at trilobites that have the bubble–no bubble difference. Both forms had to be in the same rocks, at the same level. The bubble had to be in older trilobites, not the babies. And the more trilobites found at each site, the better. The scientists did not start by going out to the rocks to look for trilobites. Instead, they went to the library.

Limulus, the horseshoe crab, is the closest living relative of trilobites. For over 100 years, its just-hatched young have been called trilobite larvae, not because of the distant relationship, but because they look like trilobites (Fortey, 2000b).

They were looking for publications in which scientists described bubbleheaded trilobites. If they could find publications describing two almost identical trilobites being found in the same rocks, only one having the bubble, so much the better. They found those and more:

- In the genus *Natmus*, the species *tuberus* has a bubble. The species *victus* has no bubble, but is otherwise identical to *tuberus*. Both are found in the same rocks (Jell, 1985).
- In the genus *Kaotaia*, the species *globosa* has the bubble. The species *magna* looks the same, but no bubble; both species are found in the same rocks (Zhang and others, 1980).
- The trilobite *Chanciaopsis heteromorphos* has bubbleheads, nonbubbleheads, and everything in between. That is, when *heteromorphos* has a bubble, it can be small, medium, or large (Sundberg, 1994). The name *heteromorphos* means "different forms."

You get the picture. We find that some of the trilobites may have had not only dinner in their heads, but the next generation too.



Brood pouches in trilobites.
Top: Cephalon and side view of a male. Middle: Cephalon and side view of a female. Bottom: Cutaway showing eggs in the pouch.
From Gon (2001).

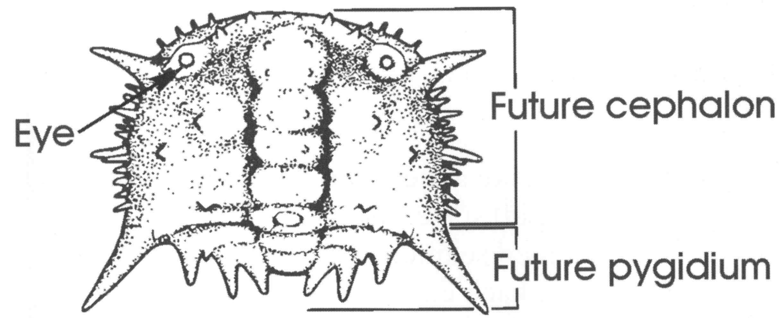
Growing up

A hatchling trilobite is called a *protaspis* (pro-TASP-iss). Some protaspides look like cute baby versions of mom and dad. They have a recognizable sort of cephalon and pygidium, but no sign of a thorax. Others look more like alien spacecraft.

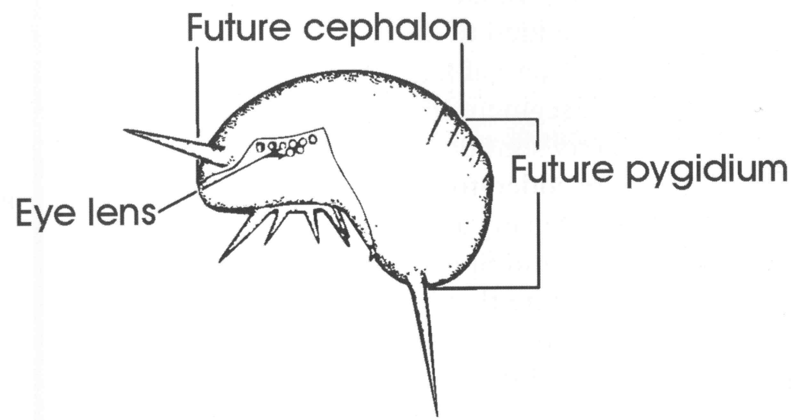
Young as they were, protaspides made hard, mineralized exoskeletons. This is why we can find them as fossils. We don't know how many times they may have molted as they grew. Right after molting, they were soft-shelled, and could grow and change before secreting calcite to harden their new shells (Chatterton and Speyer, 1997).

Many protaspides would have changed a lot as they grew up until they looked more like the trilobites they would be. That drastic change is called a metamorphosis. It happened during, or right at the very end, of the protaspid stage. In some, it happened with one molt, and in others, it took several. When a joint appeared between the cephalic area and the future pygidium, the baby was no longer a baby, and we call it a *meraspis* (mer-ASP-iss) (Chatterton and Speyer, 1997).

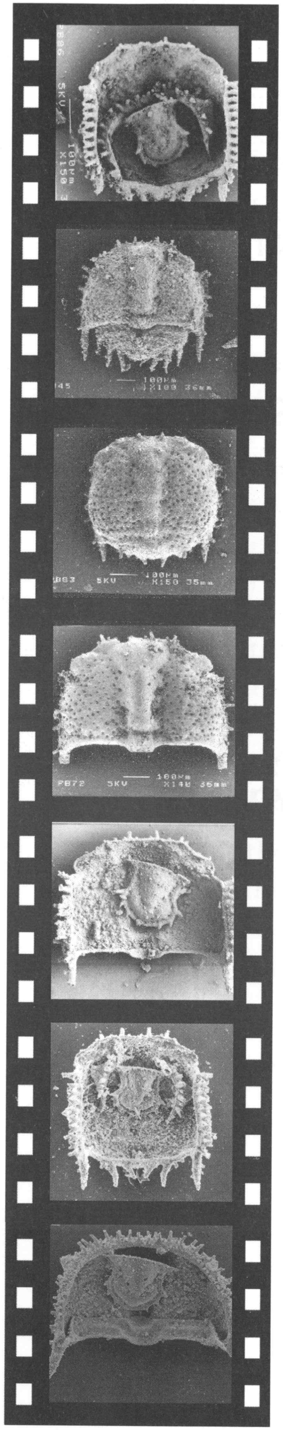
Some protaspides were really small. Five of the smallest ones could line up in 1 millimeter, with elbow room (Chatterton and Speyer, 1989).



"Cute" protaspis, top view. Adapted from Speyer and Chatterton (1989).

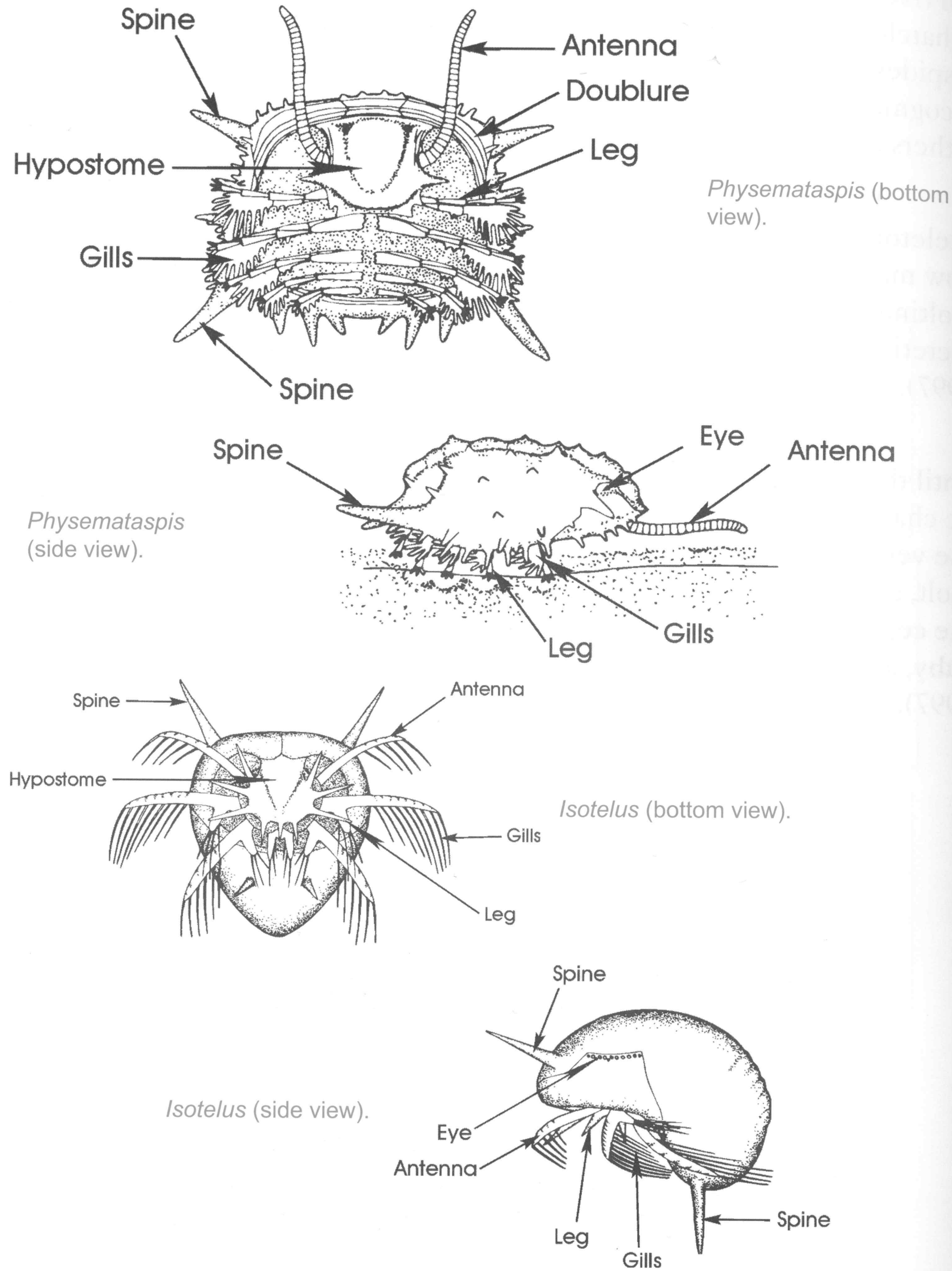


"Alien" protaspis, side view. Adapted from Speyer and Chatterton (1989).

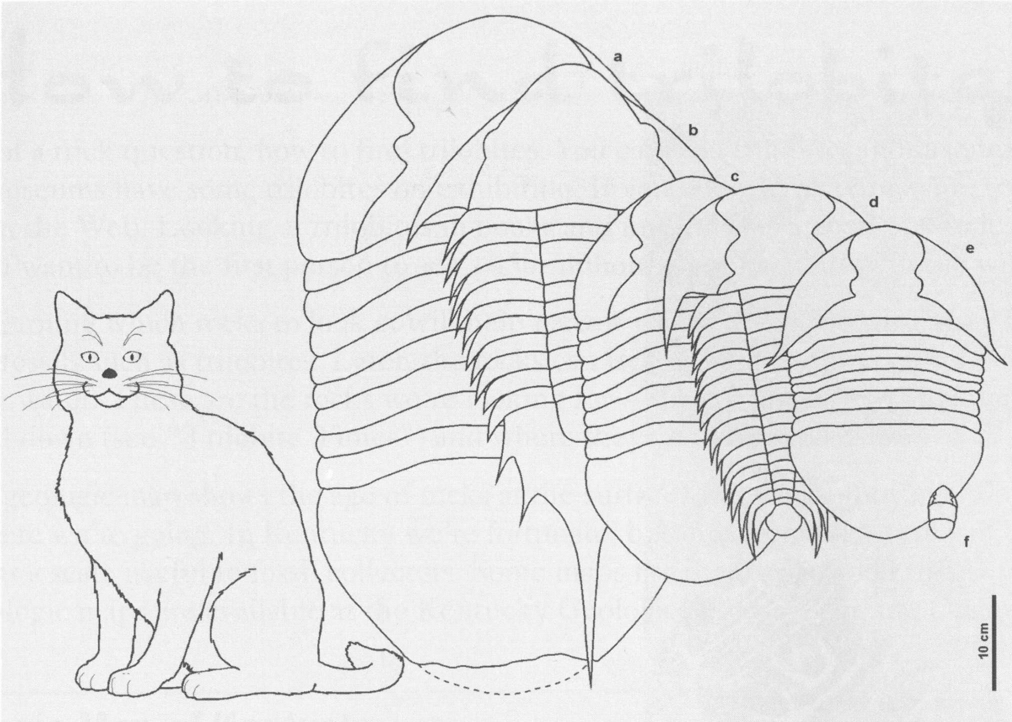


Like a teenager, during its second (meraspid) stage, the trilobite grew a lot and added segments. The segment factory was the back end, which would become the pygidium in the adult. Segments started forming near the back of the (future) pygidium. As segments were turned out, the ones in front would be released into the thorax. One (or rarely, two) segments were added to the thorax with each molt. A new pair of legs and gills came with each segment. Eventually the segment factory shut down, a few more segments were added to the thorax, and the trilobite had as many as it would ever have (Chatterton and Speyer, 1997). It was an adult. A trilobite that has grown all its segments is called a *holaspis* (hole-ASP-iss). Holaspid trilobites continued to molt and grow (Chatterton and Speyer, 1997). And some of them got quite big.

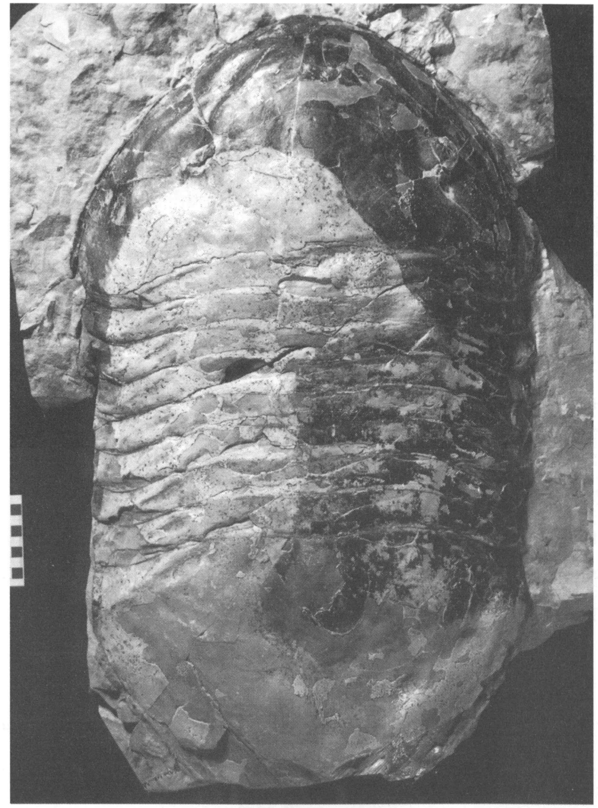
How do we know what young, growing trilobites were like? The hard exoskeletons they left behind after each molt were fairly easily fossilized. These give us snapshots of each stage of growth, as if their proud parents got out the camera for every holiday. Millions of years later, we get to flip through the family album. Photos by Brian Chatterton.



The "cute" and "alien" protaspides may have looked like these when they were alive. Adapted from Speyer and Chatterton (1989).



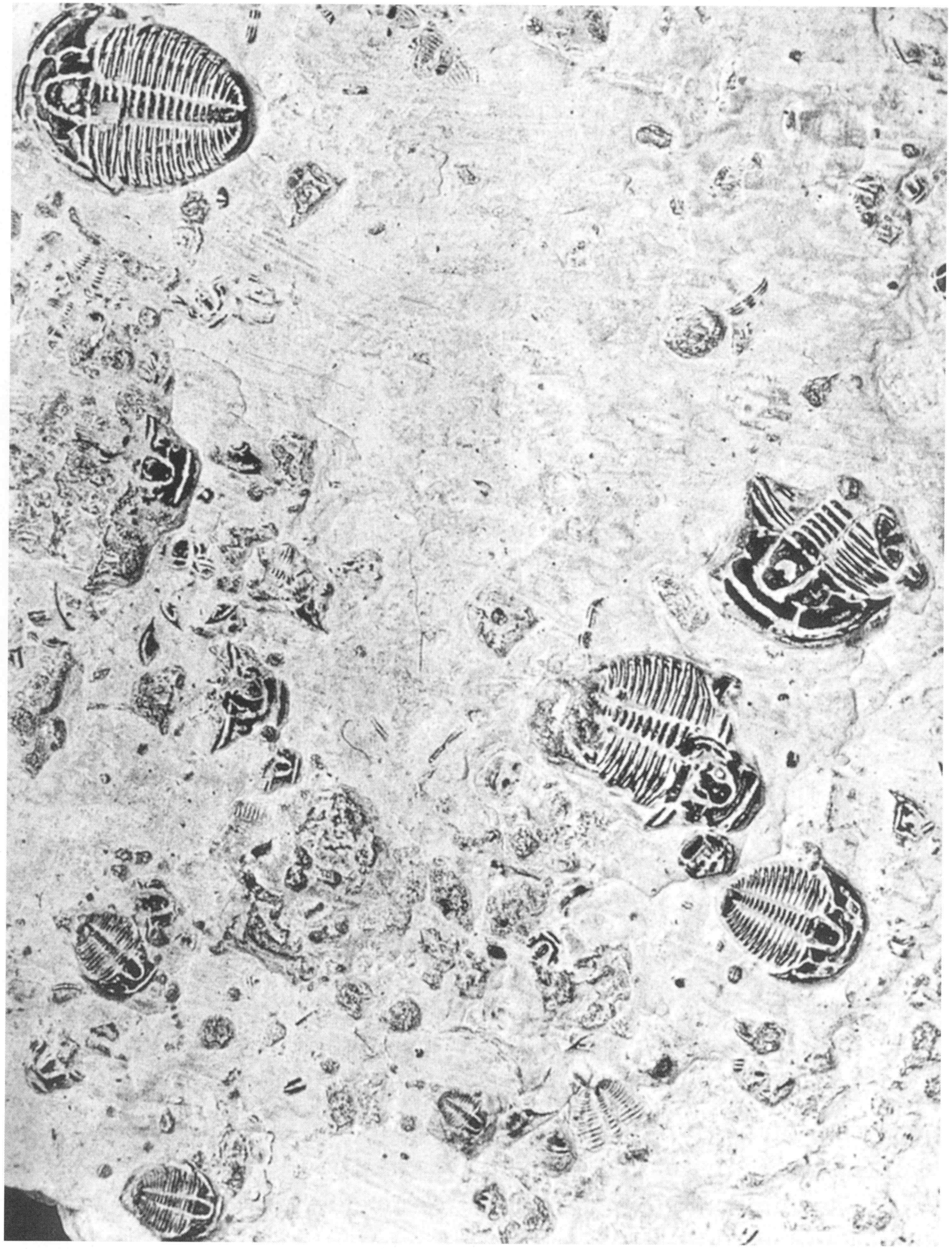
Scale drawings of giant trilobites from northern Manitoba (a, c), other big species reported from elsewhere (b, d, e), and a typical large trilobite (f). A house cat is shown for size comparison. Drawing courtesy of the Manitoba Museum of Man and Nature.



This *Isotelus* found in Canada is the world's biggest trilobite, so far. It's more than 70 centimeters long, about 28 inches. Photo courtesy of the Manitoba Museum of Man and Nature.

As their parents did, young trilobites found a variety of ways to make a living. Protaspides who looked like their parents probably had similar arrangements of limbs, if not as many. They could have walked easily over the sea floor, so we assume that they did (Chatterton and Speyer, 1997). They would have found food by grabbing or digging for small bits.

Protaspides who looked very different from their parents (the alien spacecraft type) probably could not have walked on the bottom. They would have drifted or swum in the water, feeding on tiny particles. When they changed to be like their parents, the swimming ones may have kept their swimming lifestyle, or they may have changed to crawling on the sea floor. Drifters could have gone from drifting to swimming, or crawling (Chatterton and Speyer, 1997). The lucky ones would have avoided becoming someone's dinner, and would have grown up at home in the sea, to make more little trilobites.



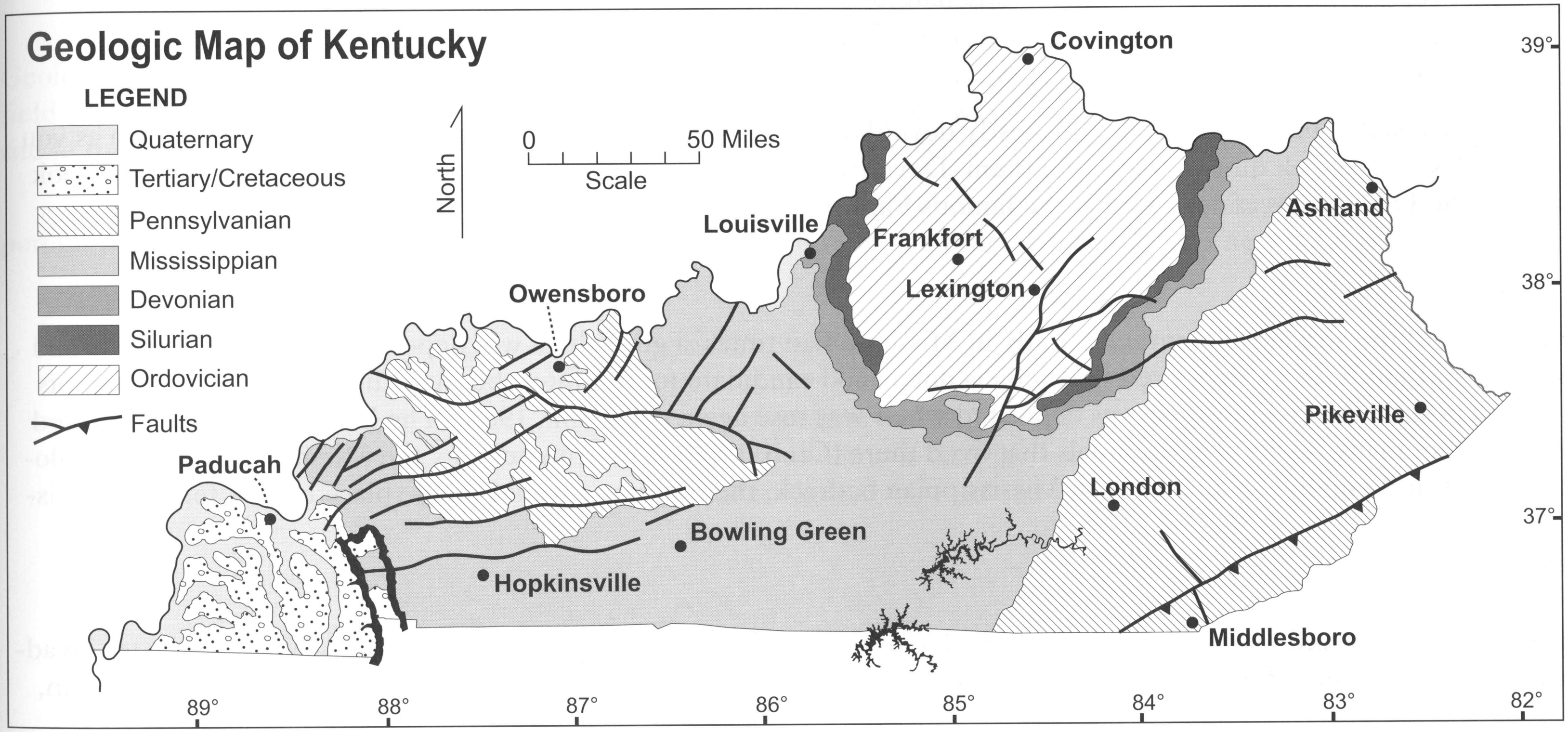
Elrathia. Can you find three stages of trilobite growth on this rock? The answer is on the inside back cover of this book. From the book *Trilobites* [2nd ed.], by Riccardo Levi-Setti (1993). Reprinted with the author's permission. © Riccardo Levi-Setti.

How to find trilobites

It's a bit of a trick question, how to find trilobites. You can find trilobites in museums, and that's an excellent place to search. Most natural history museums have some trilobites on exhibition. If you don't have a museum, try a library or the Web. Some museum collections can be viewed on the Web. Looking at trilobites in books and museums is a good way to learn about them, and to find out what they really look like. But if you want to be the first person to see a 450-million-year-old trilobite in the wild, you're going to have to go out and look at rocks.

Learning which rocks to look at will help narrow things down. Because they form at the bottom of bodies of water, sedimentary rocks preserve fossils such as trilobites. Later, the rocks can be left high and dry, either because the water level drops, or the sediments are lifted above the water. These are the rocks we're looking for—but not just any sedimentary rocks. We also need to know *when* those sediments were being laid down (see "Trilobite Times") and where they are now exposed.

A geologic map shows the age of rocks at the surface, and where they are. The best map to use is one that also shows roads, so we know where we're going. In Kentucky we're fortunate, because Kentucky is one of the few states that have been completely geologically mapped at a scale useful to fossil collectors. Some maps list the fossils (sometimes including trilobites) that have been found in the mapped area. Geologic maps are available at the Kentucky Geological Survey. See the Organizations section at the back of the book for information.



Generalized geologic map of Kentucky.

Cambrian

Trilobites were most abundant and diverse during the Cambrian. Unfortunately, Cambrian rocks are not exposed at the surface in Kentucky—they lie a thousand or more feet below the surface. Some certainly have trilobite fossils in them, but we are not likely to find them without drilling deeply for them.

Ordovician

We know that trilobites lived during the Ordovician. Luckily, Kentucky was covered by a shallow ocean during that time, and Ordovician rocks we find there are sedimentary. They *may* (no guarantees) have complete trilobites. Ordovician rocks are the oldest rocks found on the ground in Kentucky, so they would contain the earliest trilobites you can find. The rocks are hard limestones for the most part, with some shales formed late in the Ordovician (McGrain, 1983). The most common trilobites are *Flexicalymene* and *Isotelus*. Trilobite hunting in Kentucky's Ordovician rocks is excellent. That's where they are most common, and easiest to find.

Silurian

Some of Kentucky's best-preserved and prettiest trilobites are the *Gravicalymene* found in Silurian dolomite (a rock similar to limestone, but also containing magnesium). Silurian strata, however, are not as widespread as Ordovician strata. Also, trilobites found in Silurian dolomite do not weather out of the bedrock as easily as Ordovician trilobites in limestone, because dolomite is harder than limestone. Many Silurian trilobites have been destroyed by people trying to break them out of the hard dolomite with a rock hammer!

Devonian

Because most Devonian strata consist of black shales that are mostly devoid of fossil trilobites, there are not as many trilobites in them as you will find in Ordovician rocks. Expect to look quite a lot to find them. Devonian strata do contain some limestones with trilobites. If you look hard you can see trilobites in the Devonian reefs exposed at the famous Falls of the Ohio near Louisville.

Mississippian

Mississippian strata cover much of the surface of Kentucky. Early in Mississippian times, a great delta was deposited in the sea by rivers and streams, bringing muds, silts, and sands. Rock deposited in a delta is not a good candidate for trilobites, because they did not live where lots of mud and silt were being deposited. More limestone was deposited when seas rose again (McGrain, 1983). The limestones were deposited in great inland seas. They contain many fossils of the animals that lived there (Greb, 1989). Unfortunately, by the Mississippian Period, trilobites had become uncommon. But if you live in an area with Mississippian bedrock, the limestone would be the place to look for rare Mississippian trilobites.

Pennsylvanian

During the Pennsylvanian, the sea rose and fell many times. At the edge of the water, great swamps with forests grew. When the water invaded, sea life, including trilobites, took over. The land plants were later pressed under more clays, silts, and sands, and became coal (McGrain, 1983). Coal is great for finding plant fossils, but not for trilobites. Dark shales that were deposited by the Pennsylvanian seas are where trilobites can be found, but they're uncommon. The most common Pennsylvanian trilobite fossils are phillipsid pygidia.

Whenever we look for trilobites in Kentucky, the best places have rock at the surface—roadcuts, excavations, and creek beds, for instance. This way, we don't have to dig. But common courtesies and regulations should be considered. Ask permission before going on anyone's land. Drive with consideration. Stopping along many Kentucky and Federal roadways is illegal unless it's an emergency. Also, stopping along some roads can be dangerous. Use common sense. No trilobite is worth getting hit by a car or struck by lightning. Check the ground before you step or reach—Kentucky has some poisonous snakes and spiders. In summer, take a hat, lots of water, and sunscreen—and use them.

Sometimes a trilobite can just be picked up from the rocks and dirt as a complete specimen. A little cleaning with water and a toothbrush is all it needs. Other trilobites are imprisoned in the rocks. A hammer and cold chisel can be useful to separate the rocks. A brickmason's hammer, sold at most hardware and building supply stores, is an economical and effective tool. If you hammer on rocks, wear eye protection.

If you're a beginning fossil collector, the very best way to find trilobites is to go with a museum or amateur group. Call the Kentucky Geological Survey or check their Web site (see the References and Organizations sections at the end of this book for information). Guided field trips conducted by the Kentucky Paleontological Society are a good way to learn the rocks, learn the fossils, and have fun (see their Web site in the References and Organizations sections at the end of this book).

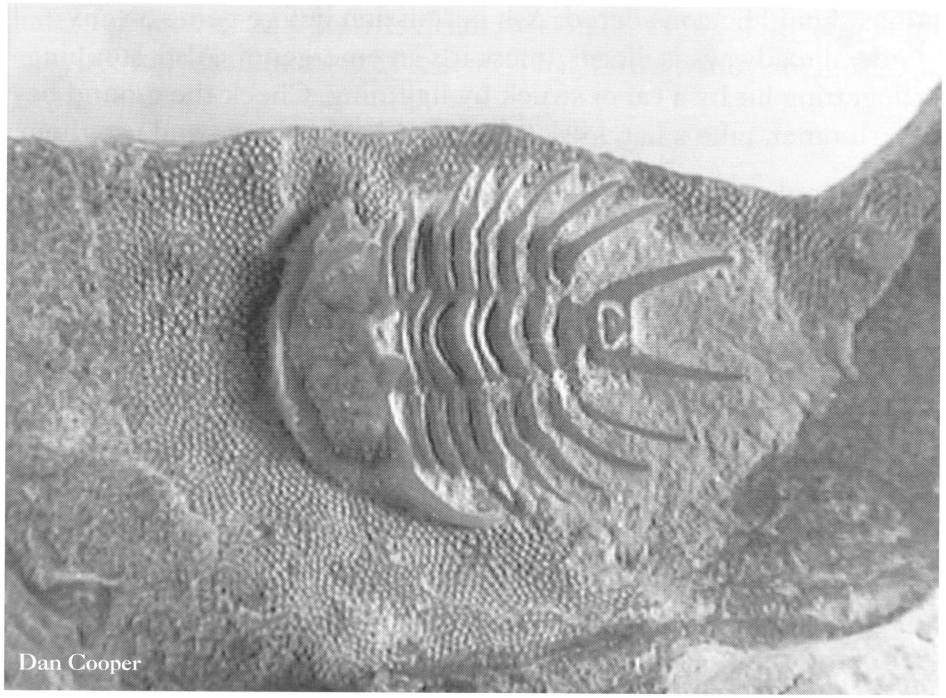
One more thing: you'll probably look at a few million trilo-bits for every complete trilobite you find. So you'll need another very important piece of equipment: patience. Because the person who finds the best trilobites is the one who looks the most. Good hunting!

Trilobite genera found in Kentucky

These photos show some—not all—of the trilobites found in Kentucky, with some notes on the most common ones. They also show that not every trilobite you find will be perfect. They are listed by period—Ordovician through Pennsylvanian. The genus name comes first, followed by the name of the person who first described the genus, then the year that description was published. Notes and photos follow that.

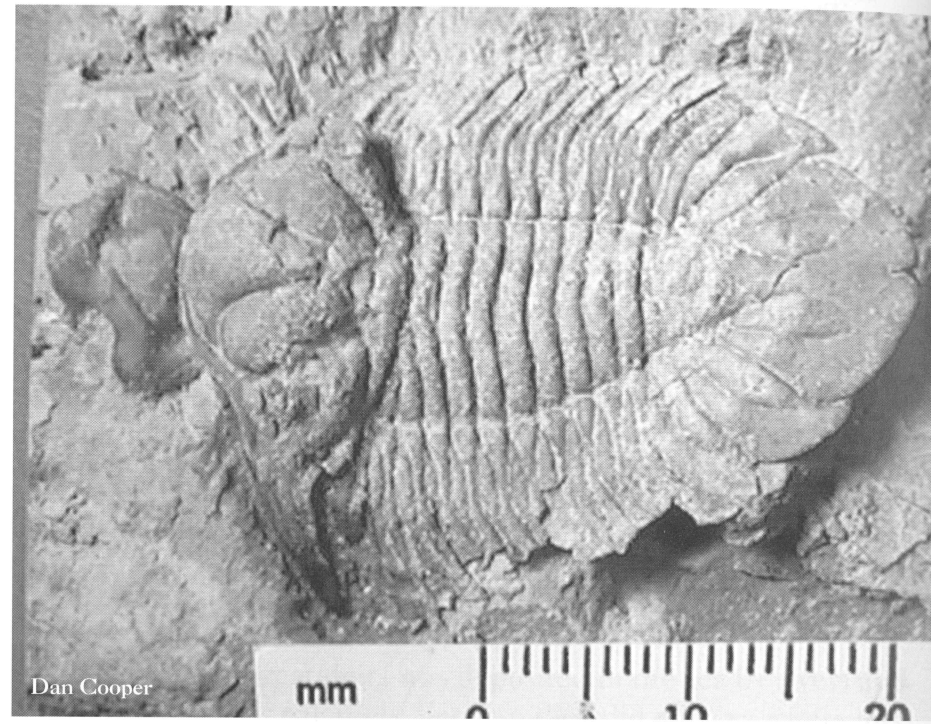
Ordovician

Acidaspis Murchison, 1839



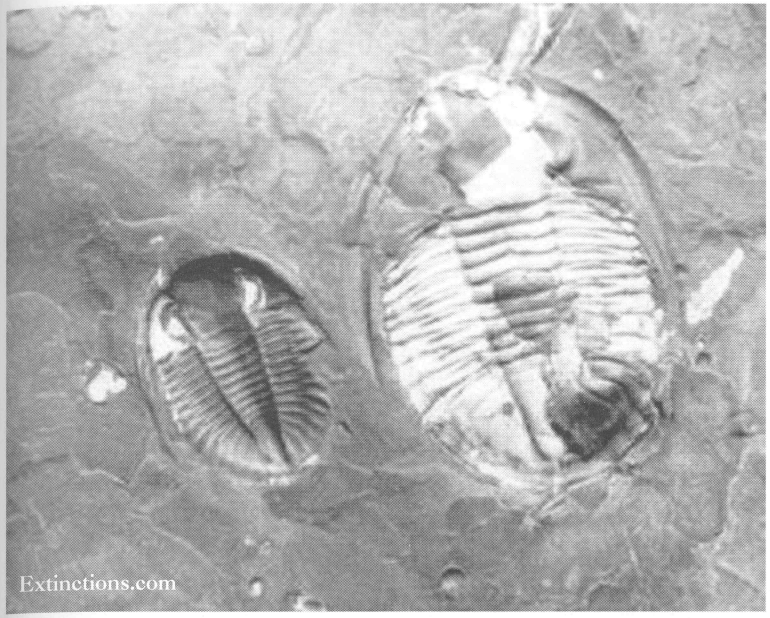
Acidaspis.

Amphilichas Raymond, 1905



Amphilichas. Photo courtesy of Dan Cooper.

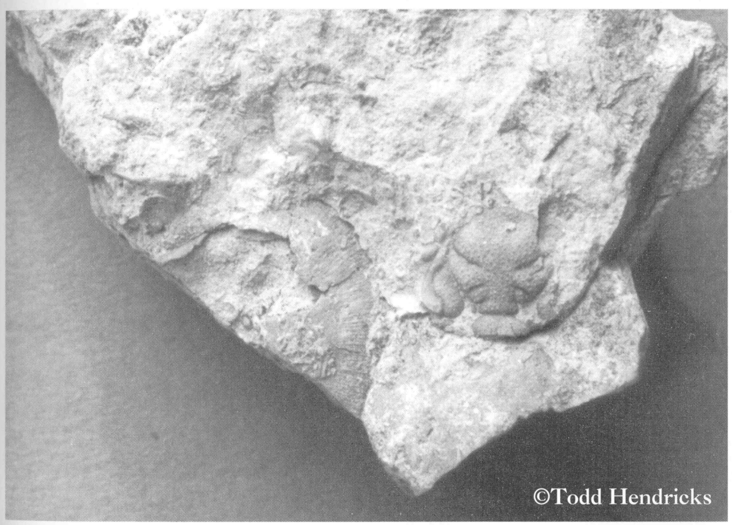
Bathyurus Billings, 1865



Bathyurus.

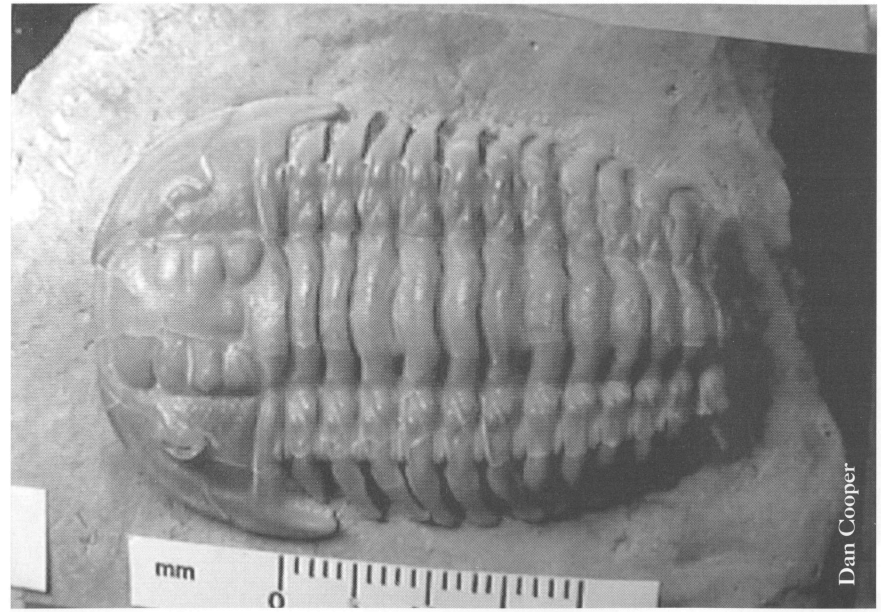
Calyptaulax Cooper, 1930

Also known as *Calliops*

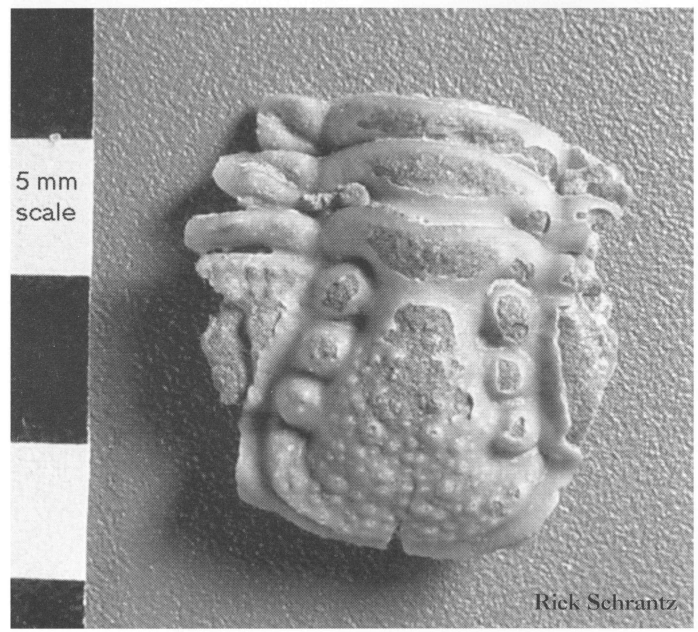


Calyptaulax cephalon.

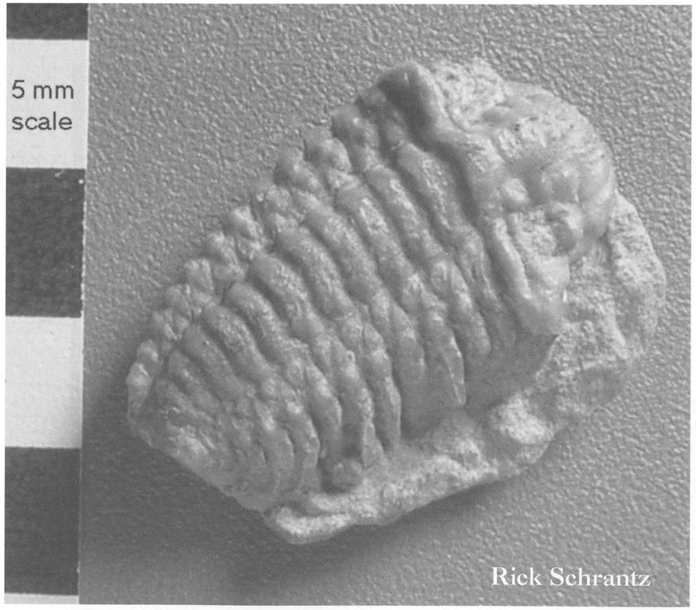
Ceraurinus Barton, 1913



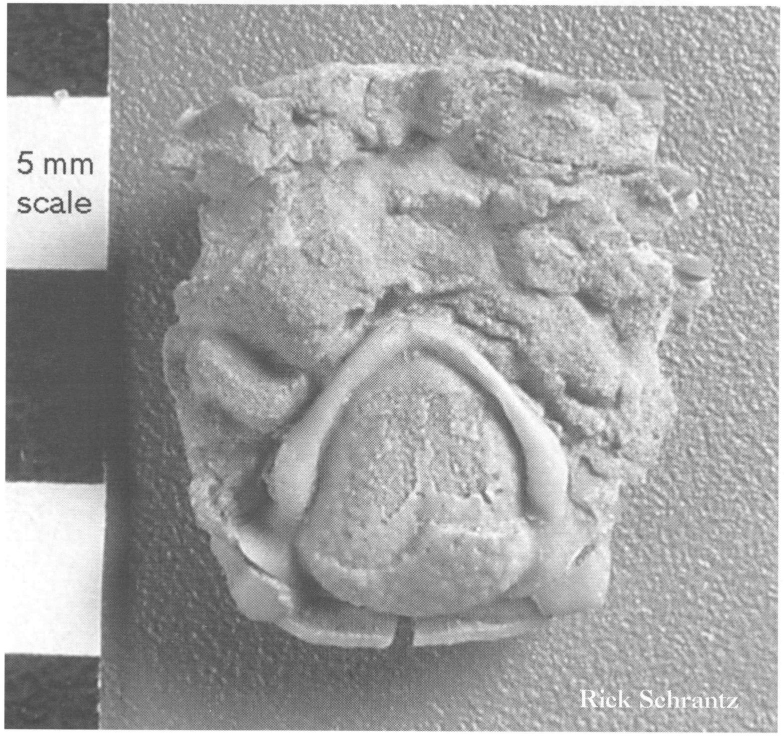
Ceraurinus.



Ceraurinus cephalon.



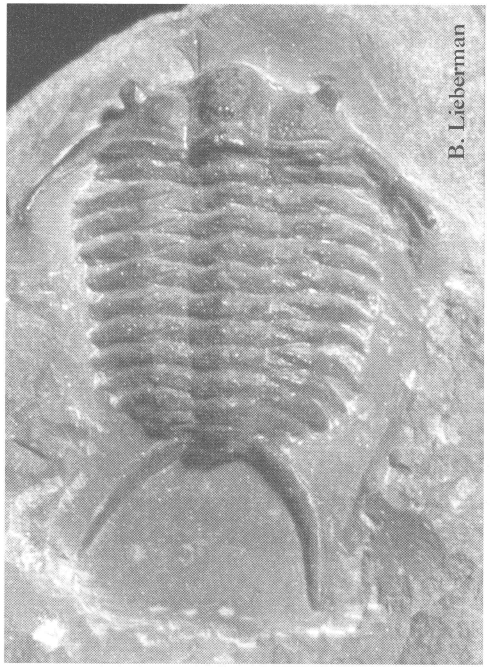
Ceraurinus.



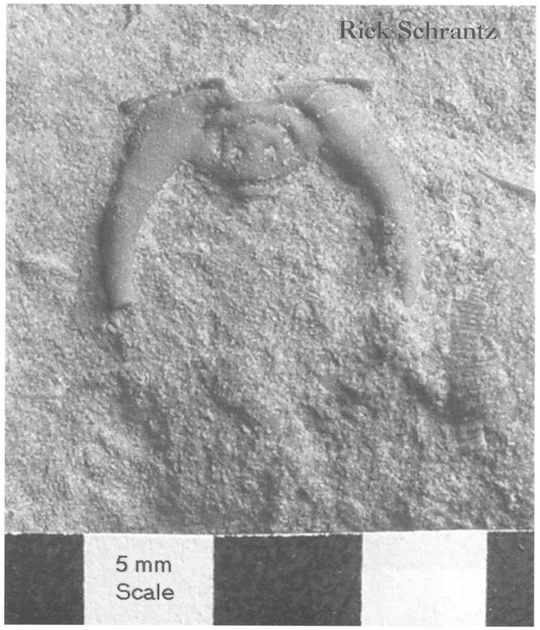
Ceraurinus hypostome.

Ceraurus Green, 1832

Ceraurus is also found in Silurian rocks.



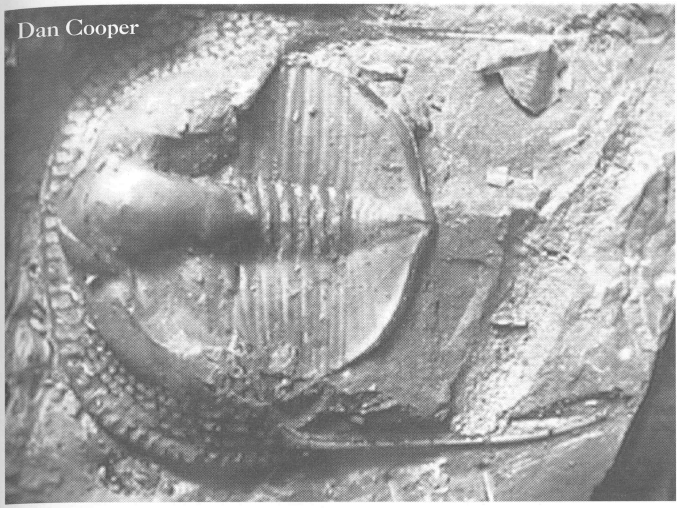
Ceraurus pleurexantheus. YPM 6571. Courtesy of the Peabody Museum of Natural History, Yale University, New Haven, Conn. The *Ceraurus* found in Kentucky is *Ceraurus icarus.*



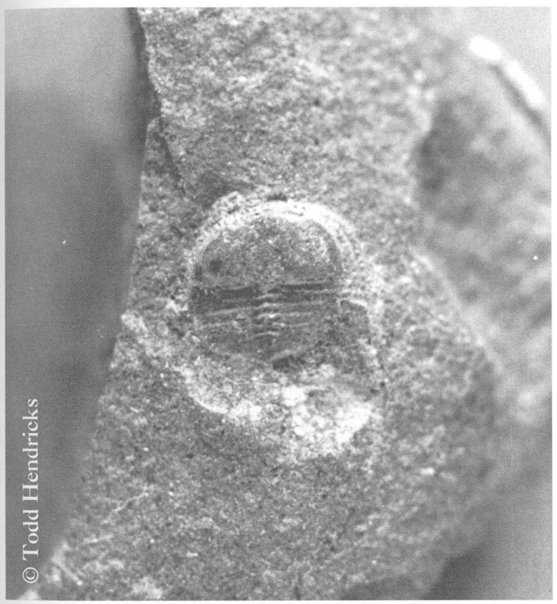
Ceraurus pygidium.

Cryptolithus Green, 1832

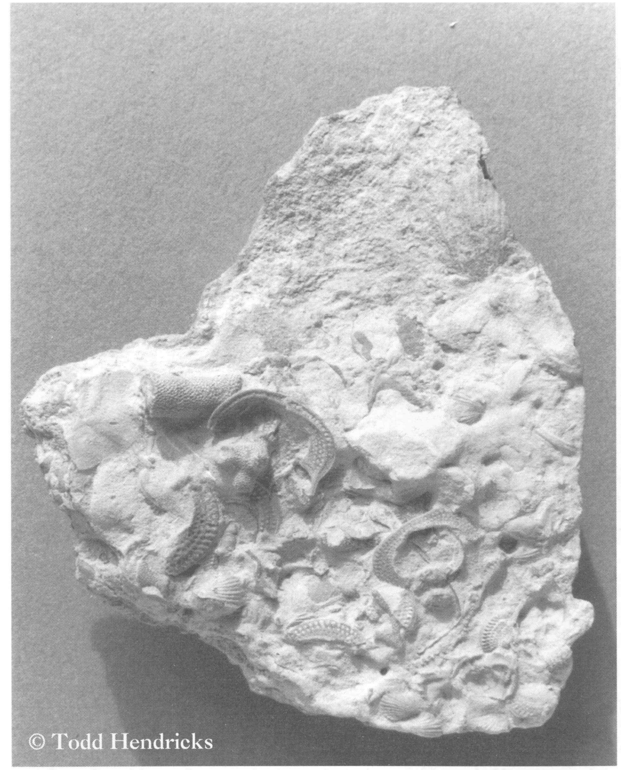
Cryptolithus can be common—even abundant—in some rocks. It is, however, extremely rare to find a complete, or even fairly complete one. The usual find is fragments of the "cowcatcher" free cheeks. A complete *Cryptolithus* could be an inch or so long.



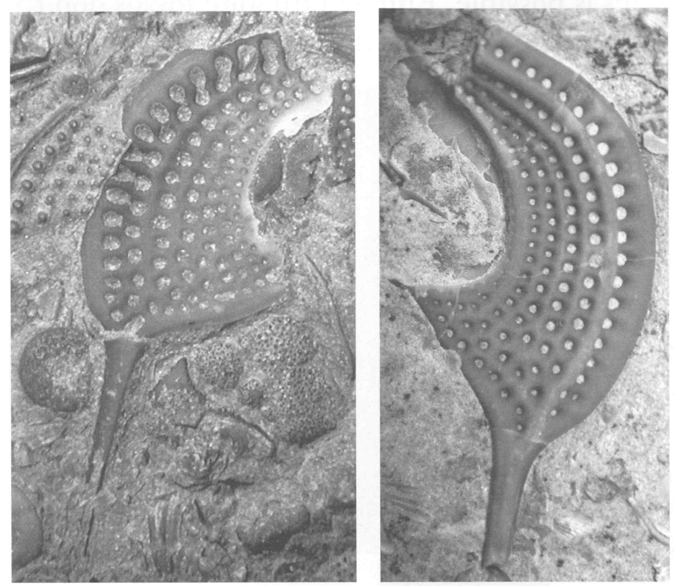
Cryptolithus tessellatus. A great specimen.



Cryptolithus tessellatus. A very good find.



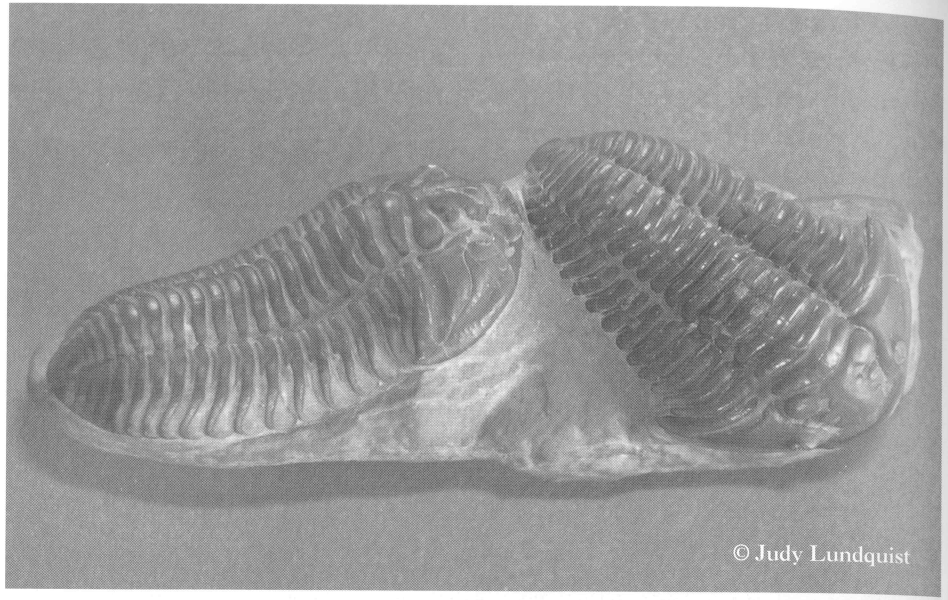
Cryptolithus tessellatus fragments. This is the way *Cryptolithus* is almost always found.



Cryptolithus tessellatus free cheeks with genal spines. Note the unusual pits. Photos courtesy of the University of Georgia.

Decoroproetus parviusculus Bancroft, 1949

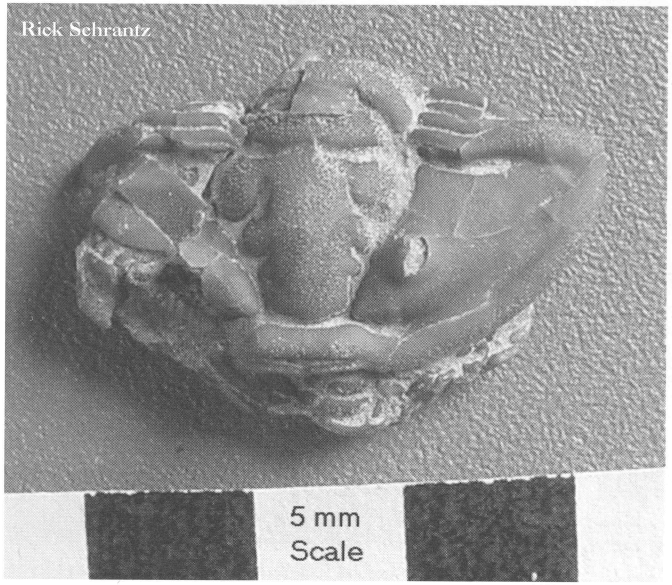
Decoroproetus parviusculus pygidium. Also known as *Proetidella.* Photo courtesy of the University of Georgia.



Flexicalymene.

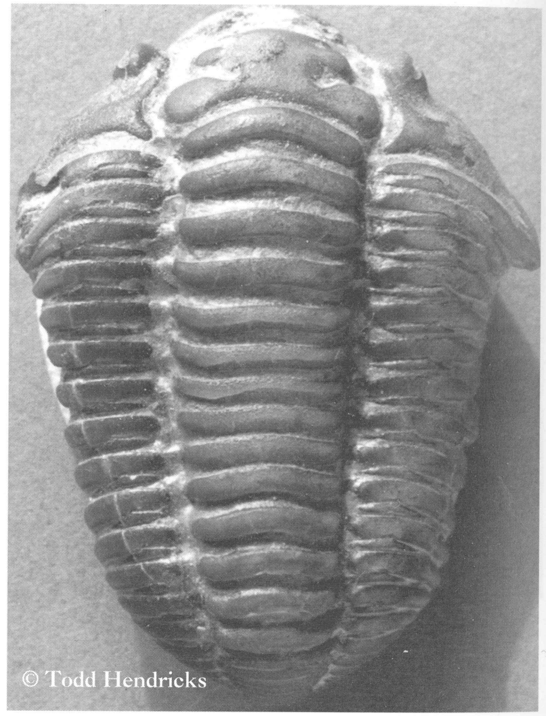
Flexicalymene Shirley, 1936

Flexicalymene meeki is one of the most common trilobites found in Kentucky. You can find pieces of them easily. It's only a little harder to find fairly complete ones, including molts in various states of disintegration. Complete *Flexicalymene* are usually enrolled, although finding outstretched ones is possible. Enrolled trilobite fossils don't break up as easily as outstretched ones, so there are more of them.



Flexicalymene can be quite small, but are typically up to 2 inches long if outstretched.

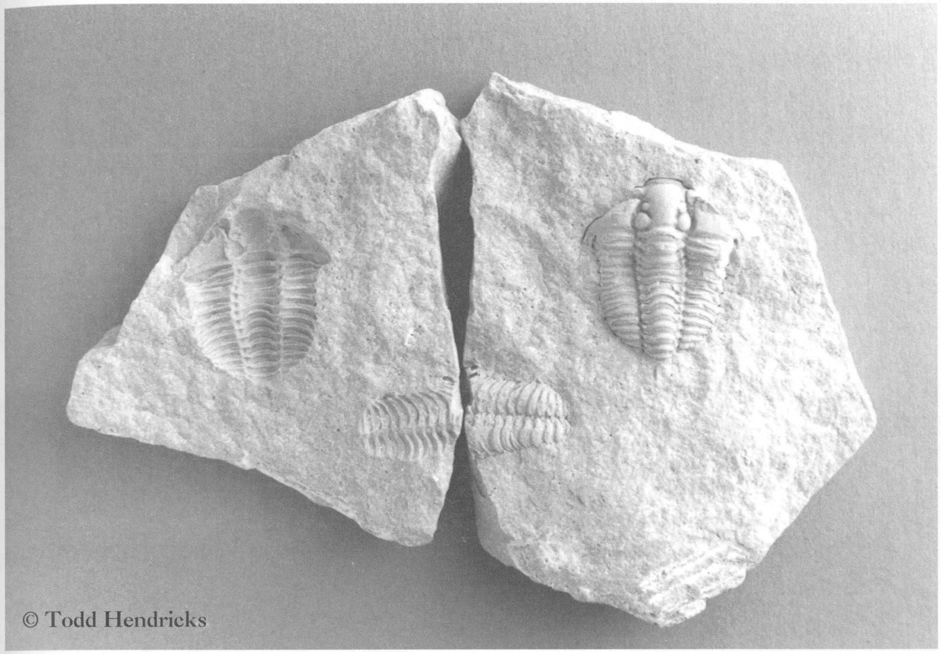
Enrolled *Flexicalymene granulosa.* Notice the small bumps on the surface.



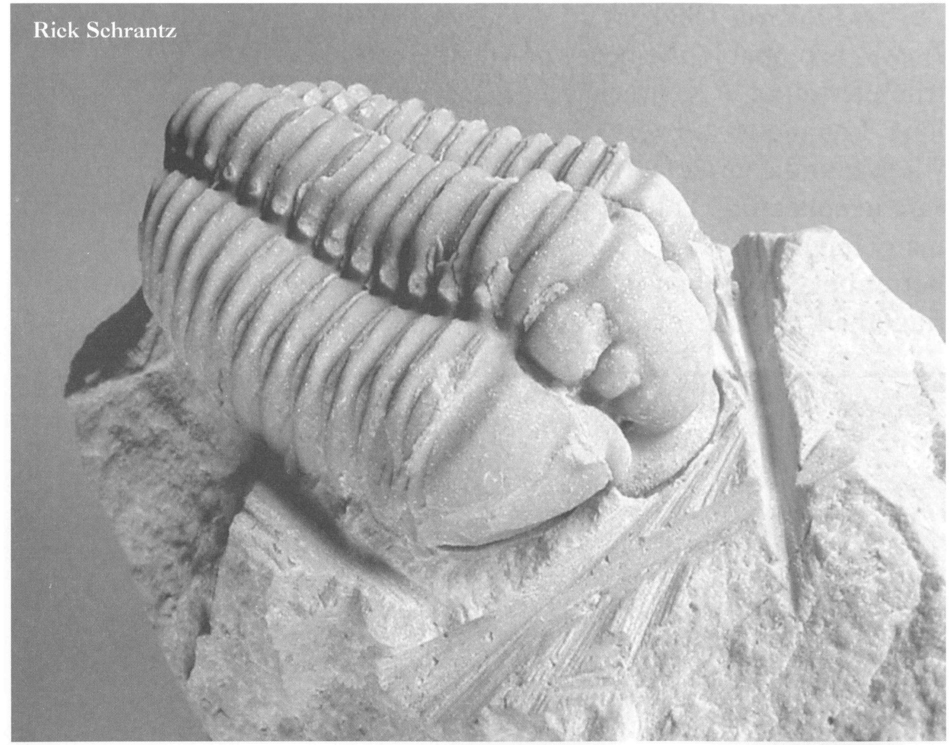
Flexicalymene meeki.

Gravicalymene Shirley, 1936

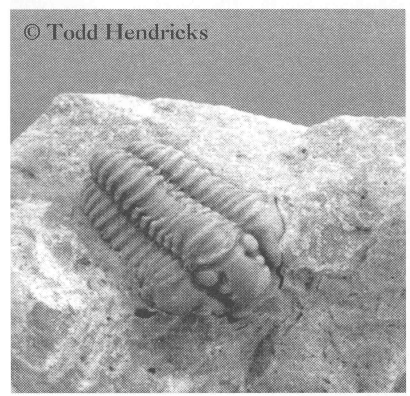
Although it also occurs in Ordovician rocks, *Gravicalymene* is commonly found in Silurian rocks. They are difficult to remove from the rock without breaking, but the effort is well worth it. Enrolled ones are rare.

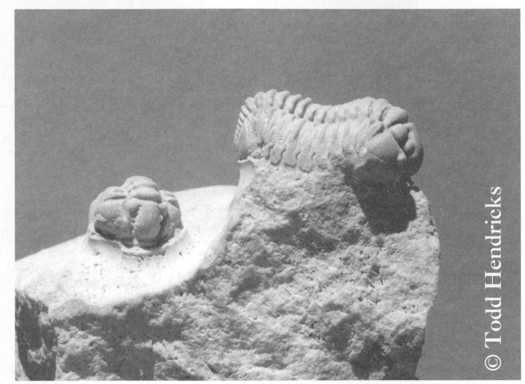


Gravicalymene celebra, part and counterpart. The trilobite was completely enclosed in the rock. When the rock was broken to reveal it, the trilobite (part) left a mold of itself (counterpart) in the rock.



Gravicalymene celebra.

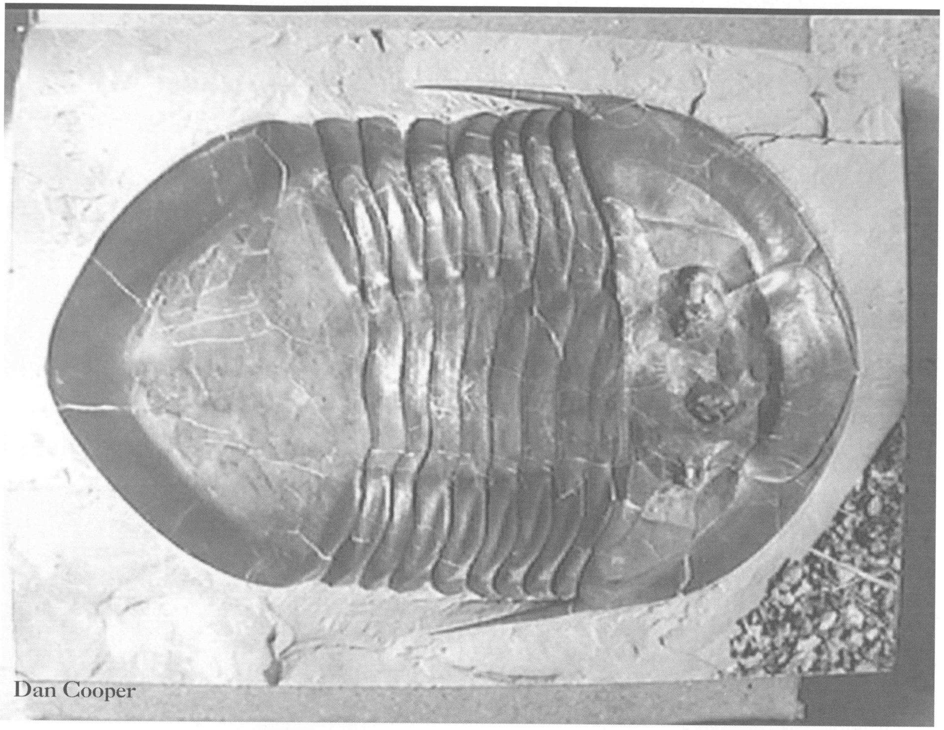




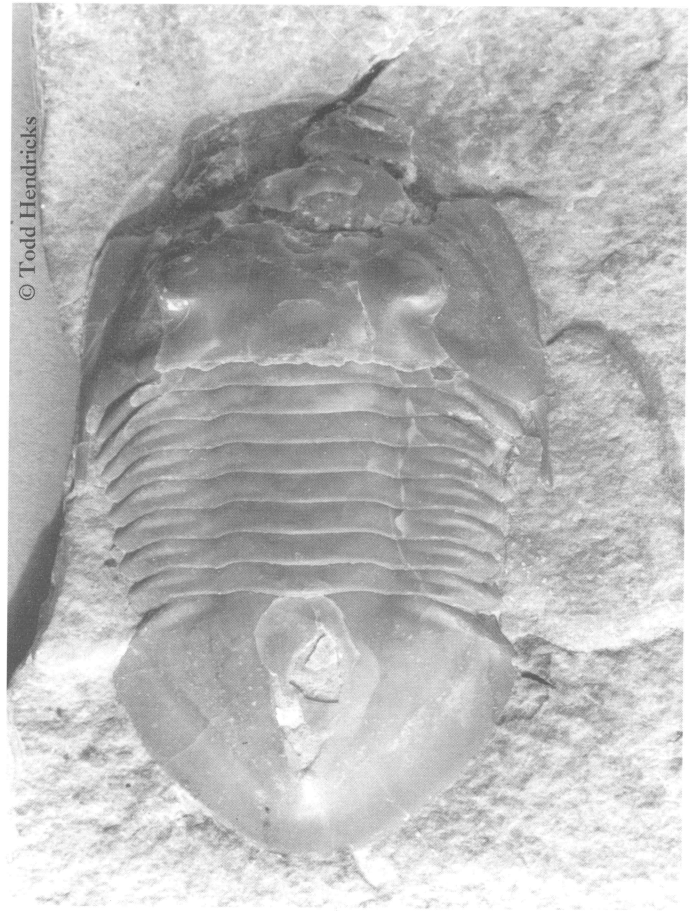
Gravicalymene celebra.

Isotelus DeKay, 1824

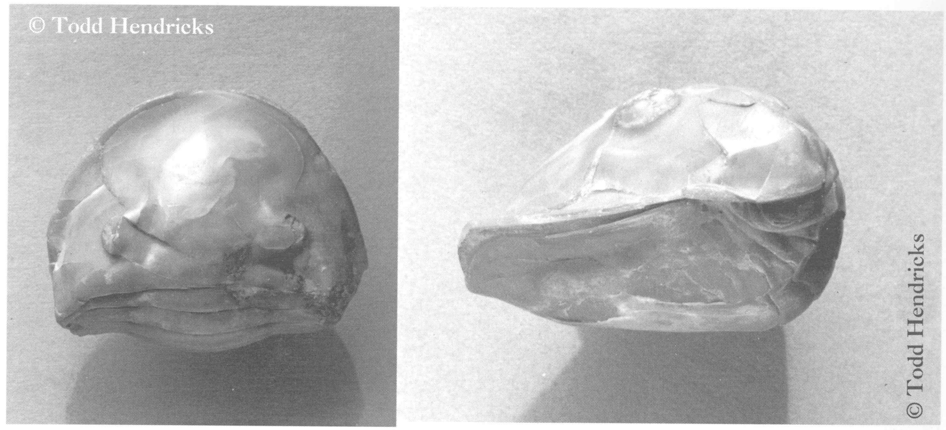
Isotelus is probably the best known, and certainly the biggest, trilobite found in Kentucky. They may have grown up to 2 feet long. Fragments are very common; complete *Isotelus* are rare. Even when found complete, they are quite fragile and require extreme care in collecting. You may have to reassemble the trilobite from many fragments. If you want a complete one, enrolled *Isotelus* are a better bet. These can be very small, less than the size of your little fingernail. Expect to look long and hard to find a good one.



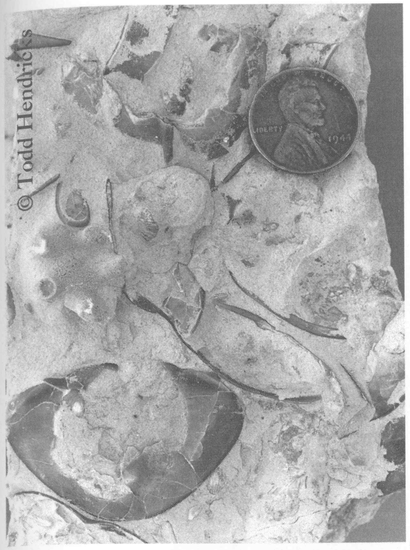
Isotelus maximus. This specimen is nearly complete, including the genal spines.

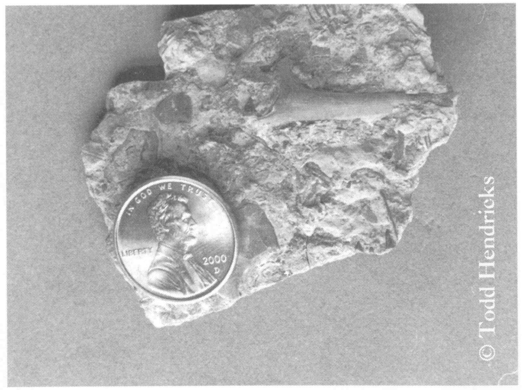


Isotelus. This is an exceptional specimen, though not

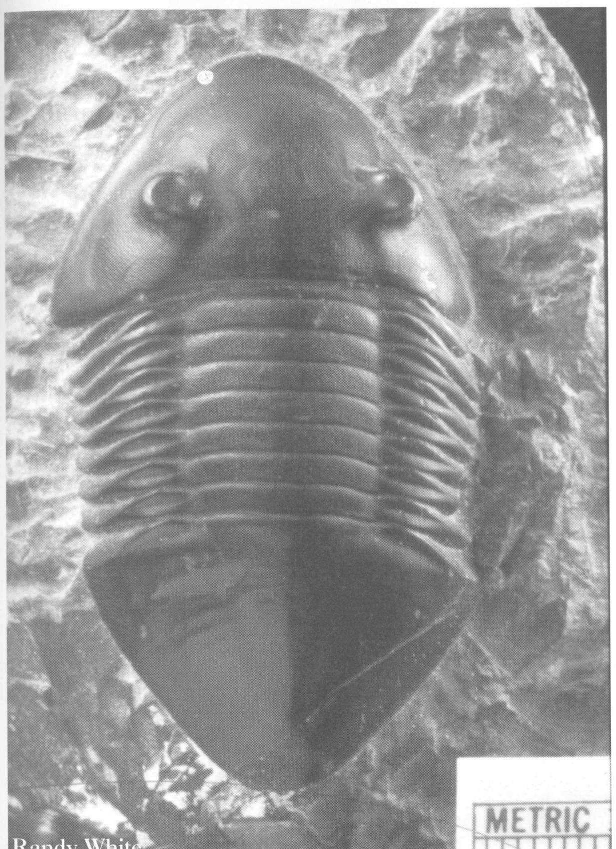


Two views (top and side) of an enrolled *Isotelus.*



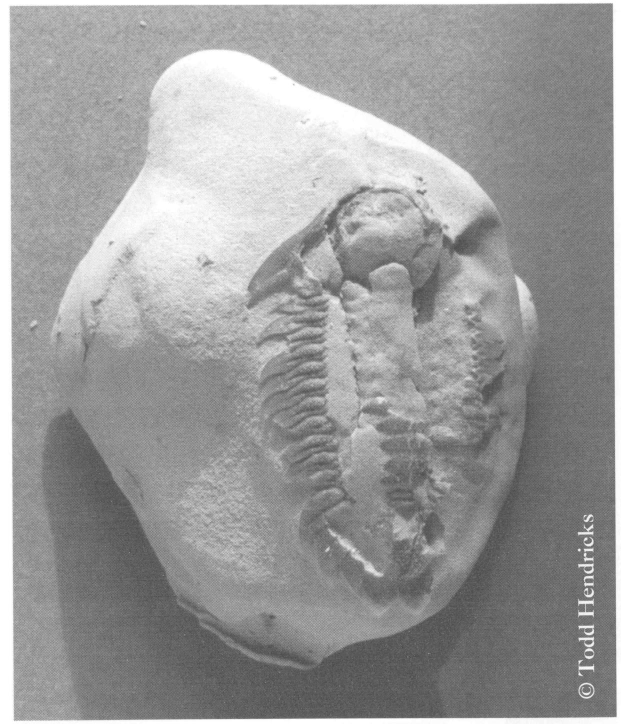


Isotelus maximus fragments. On the right, a genal spine. Fragments of *Isotelus* are common.



Isotelus gigas. YPM 6690. Courtesy of the Peabody Museum of Natural History, Yale University, New Haven, Conn.

Platylichas Gurich, 1901

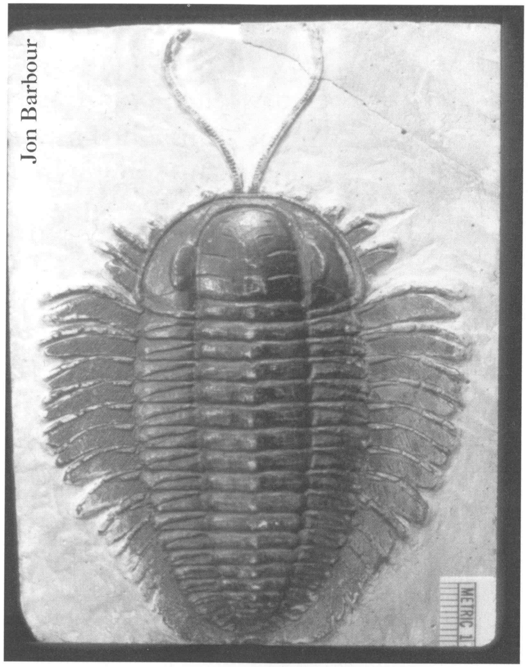


Platylichas.

Primaspis Richter and Richter, 1917

Primaspis.

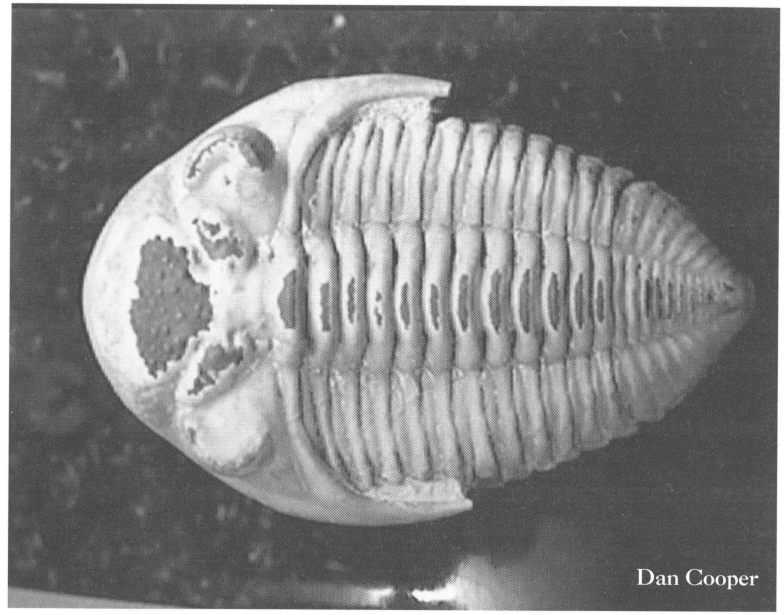
Triarthrus Green, 1832



Triarthrus etoni Hall. YPM 37035. Courtesy of the Peabody Museum of Natural History, Yale University. This is a model of the trilobite as it may have looked in life.

Triarthrus etoni Hall. YPM 228. Courtesy of the Peabody Museum of Natural History, Yale University, New Haven, Conn.

Tricopelta Ludvigsen and Chatterton, 1982

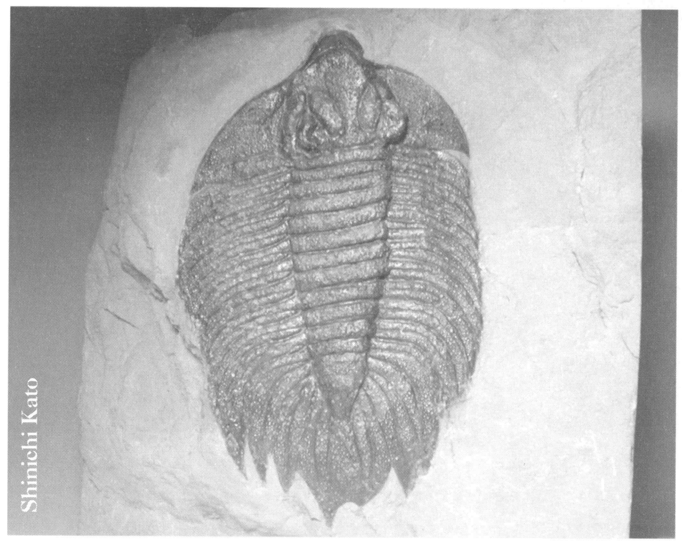


Tricopelta breviceps. Previously known as *Chasmops breviceps.*

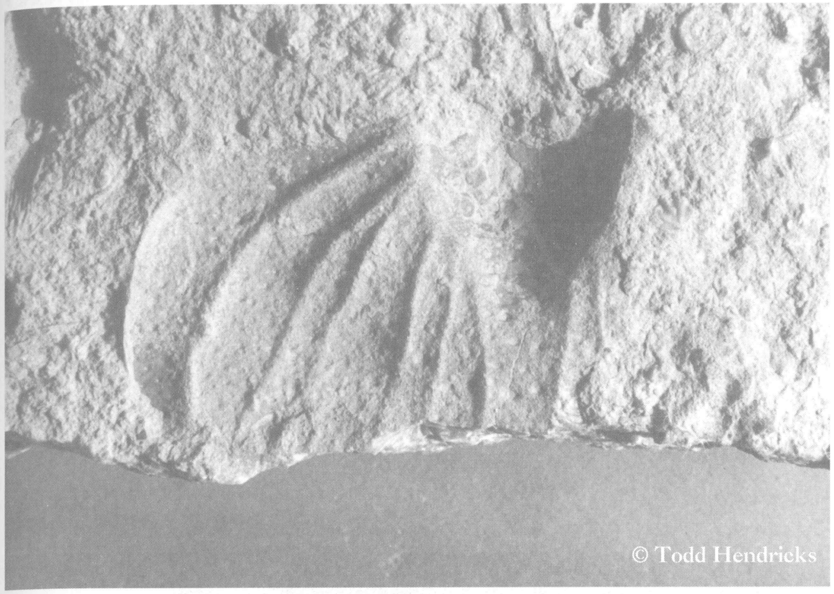
Silurian

Arctinurus Castelnau, 1843

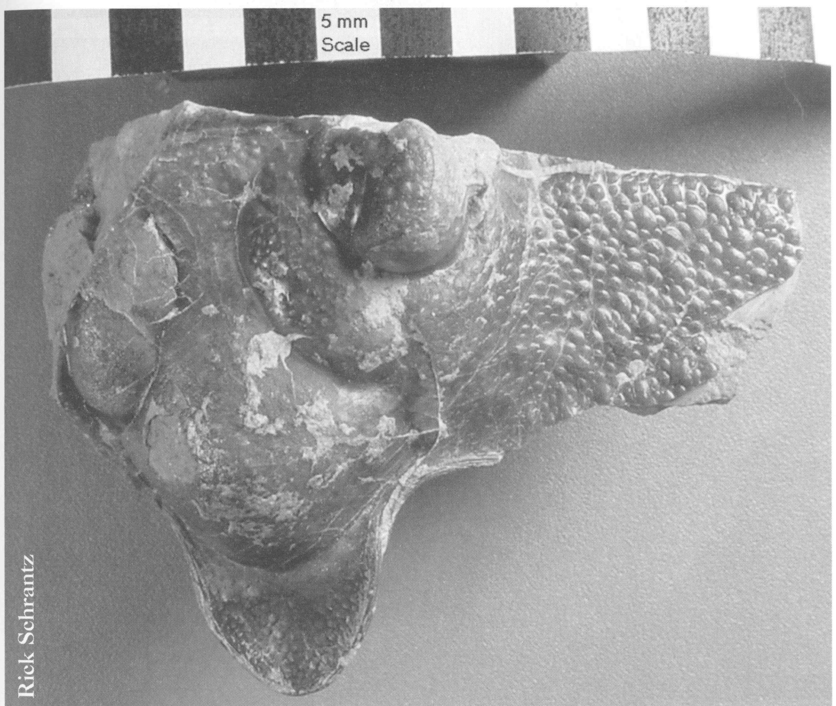
Arctinurus also occurs in Devonian rocks. It is fairly rare.



Arctinurus.

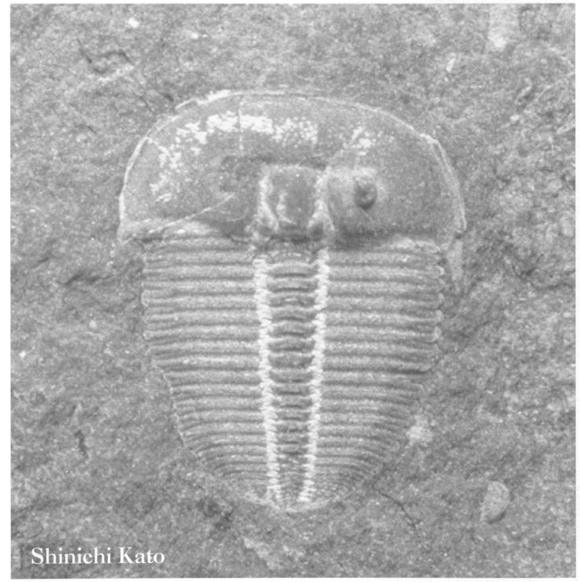


Mold of incomplete *Arctinurus* pygidium.



Incomplete *Arctinurus* cephalon. Note the lip at the bottom of the photograph.

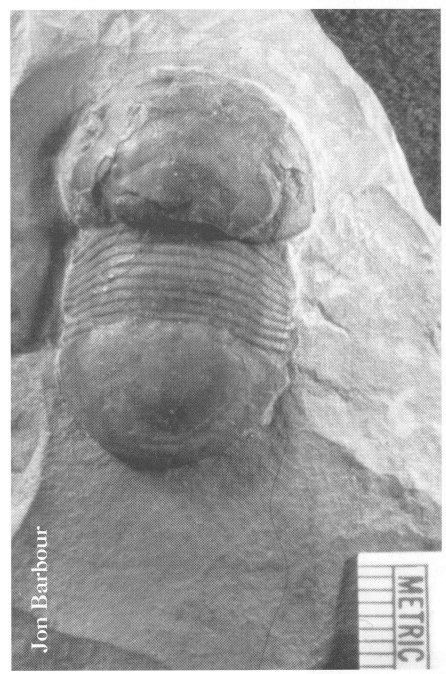
Aulacopleura Hale and Corda, 1847



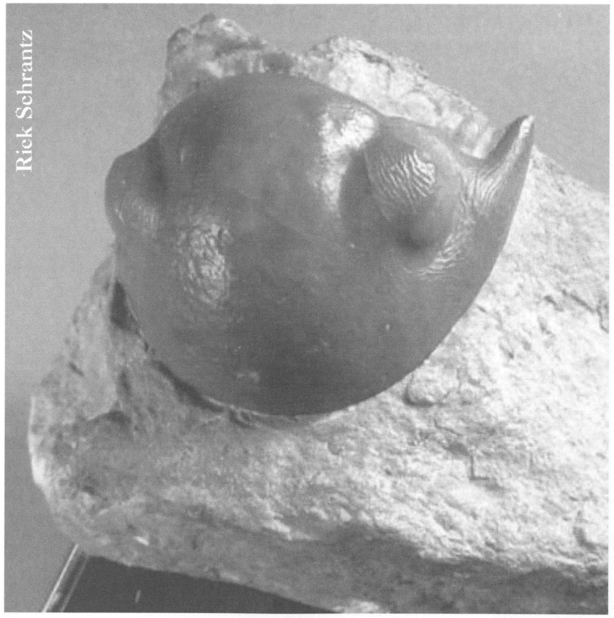
Aulacopleura.

Bumastus Murchison, 1839

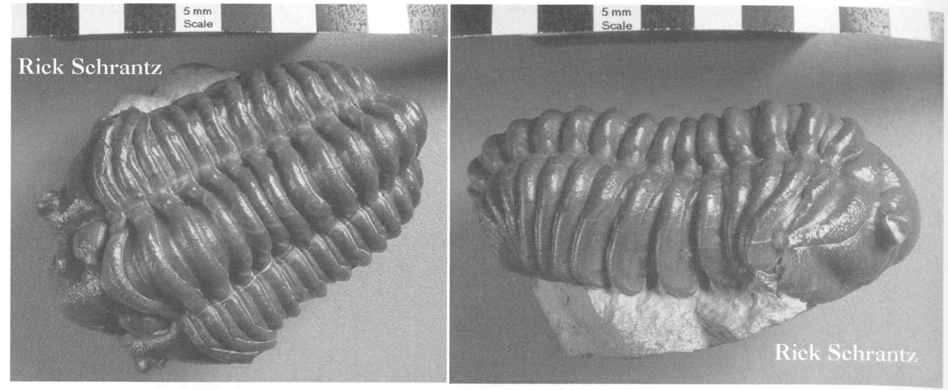
A complete *Bumastus* is very rare.



Bumastus ioxus. YPM 73387. Courtesy of the Peabody Museum of Natural History, Yale University, New Haven, Conn. Photo courtesy of Jon Barbour.



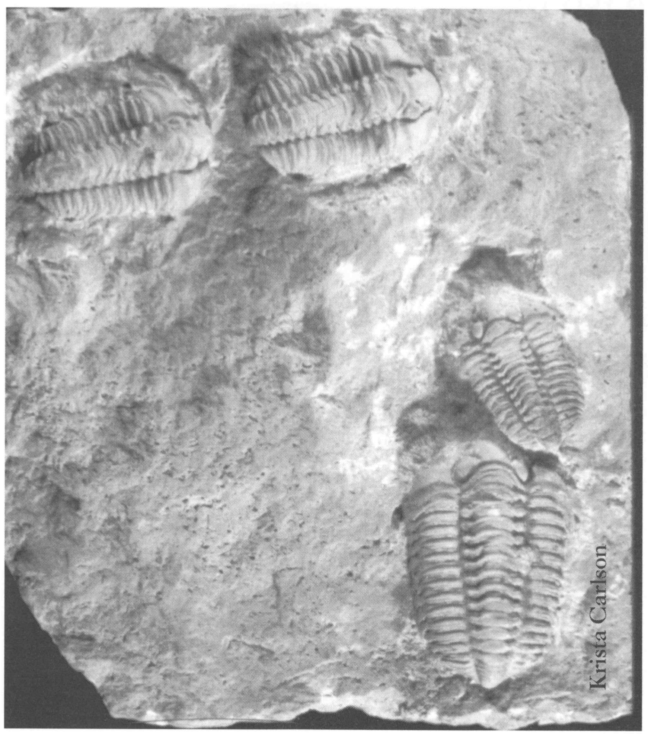
Bumastus cephalon.



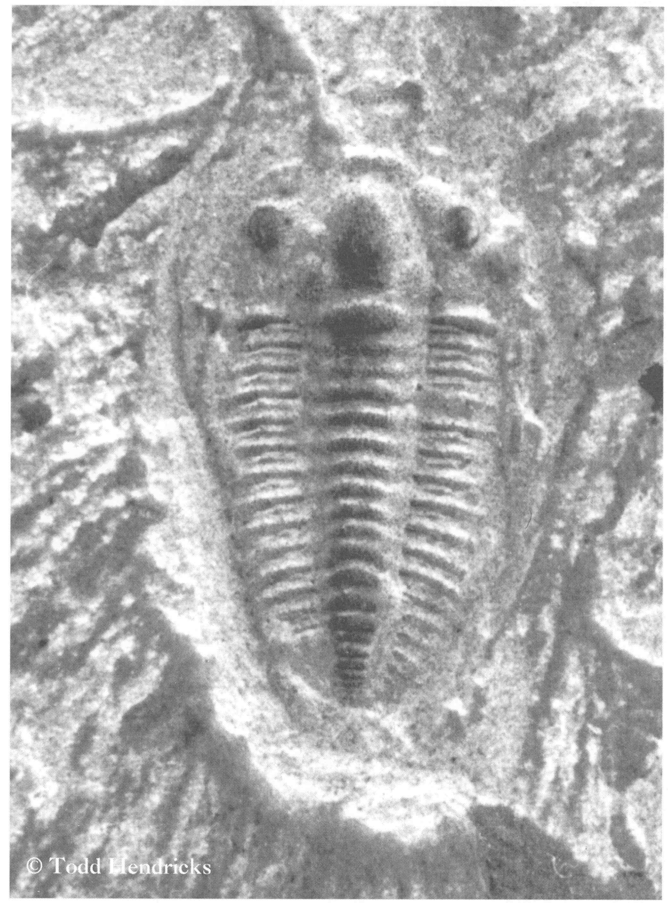
Top and side views of *Calymene breviceps*.

Calymene Brongniart, 1822

Calymene also occurs in Devonian rocks.



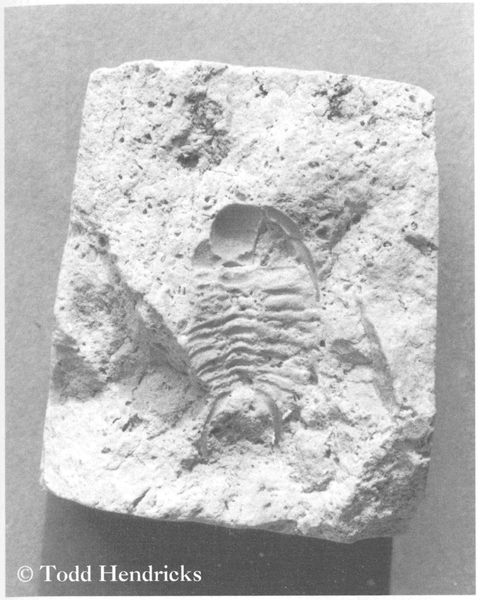
Calymene. YPM 7304. Courtesy of the Peabody Museum of Natural History, Yale University, New Haven, Conn.



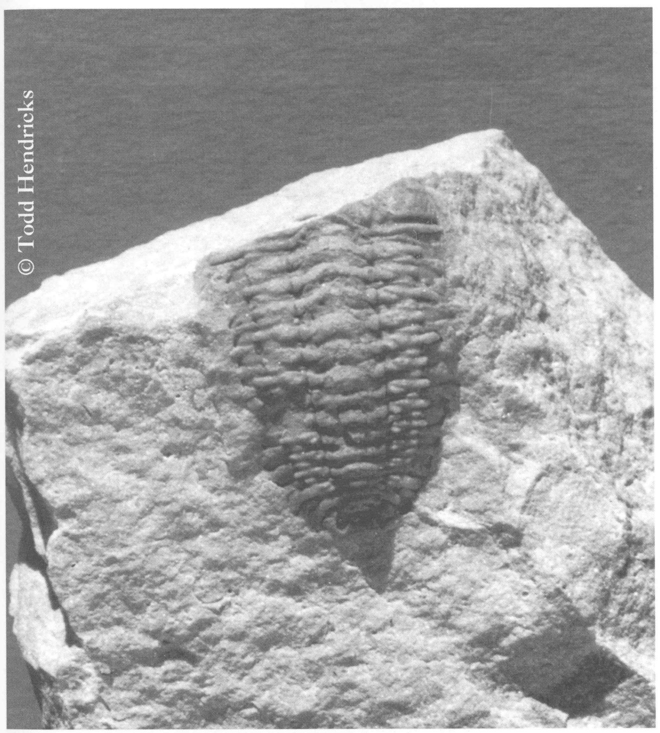
Calymene granulosa. Photo courtesy of the University of Kentucky.

Cheirurus Beyrich, 1845

Cheirurus is extremely rare.



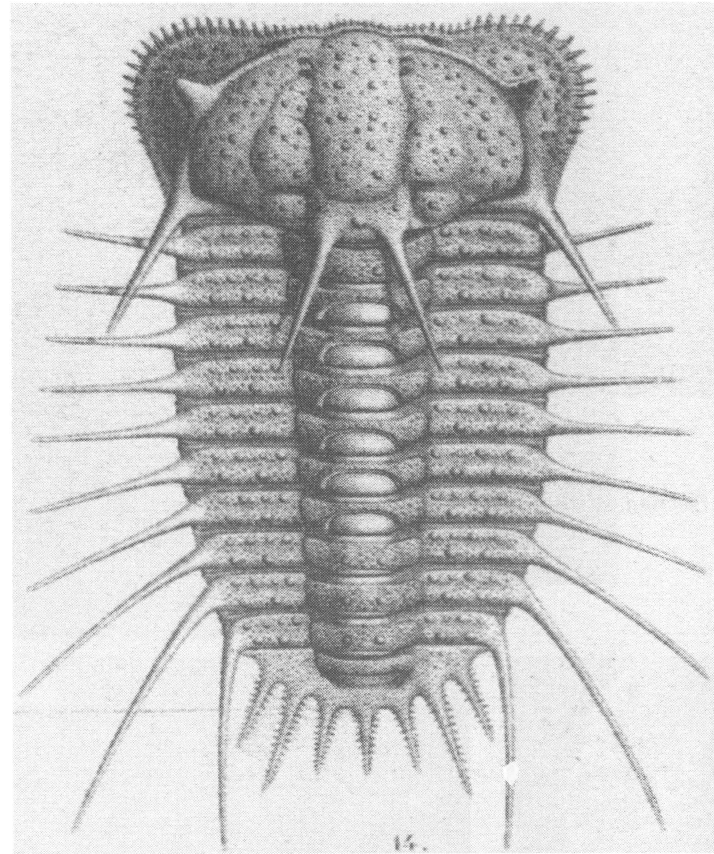
Cheirurus hydei.



Cheirurus niagarensis.

Ceratocephala Warder, 1838

Ceratocephala, illustrated by Joachim Barrande in 1852. *Ceratocephala* is very rare; only one specimen is known so far from Kentucky.



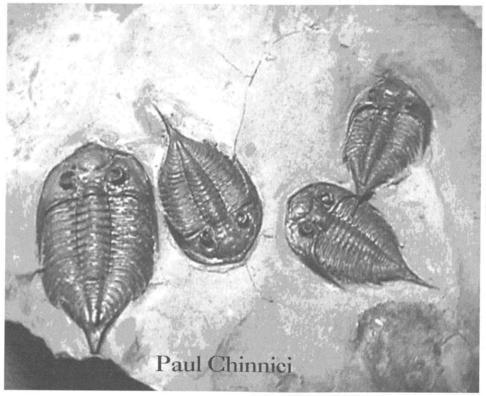
Ceratocephala.

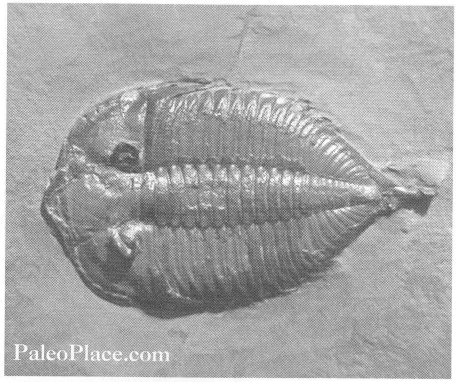
Ceraurus Green, 1832

Pictured in Ordovician section.

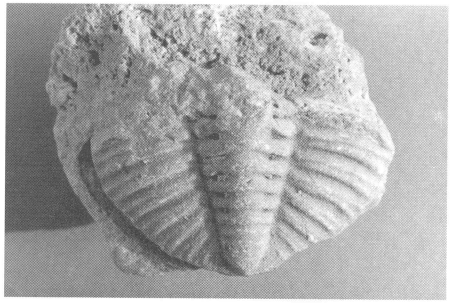
Dalmanites Barrande, 1852

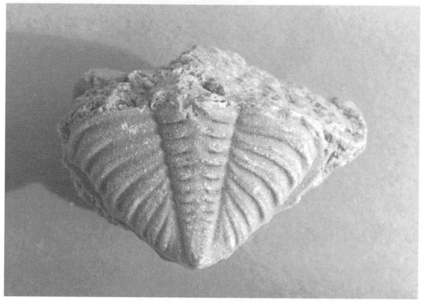
Dalmanites also occurs in Devonian rocks. Trilobites of the dalmanitid family are fairly rare.





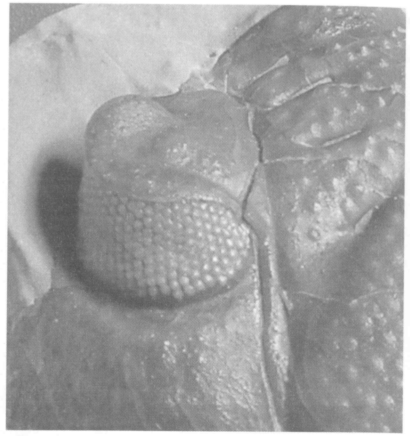
Dalmanites limulurus.





©Todd Hendricks

Dalmanitid pygidia. These are from the dalmanitid family, but are not identifiable.

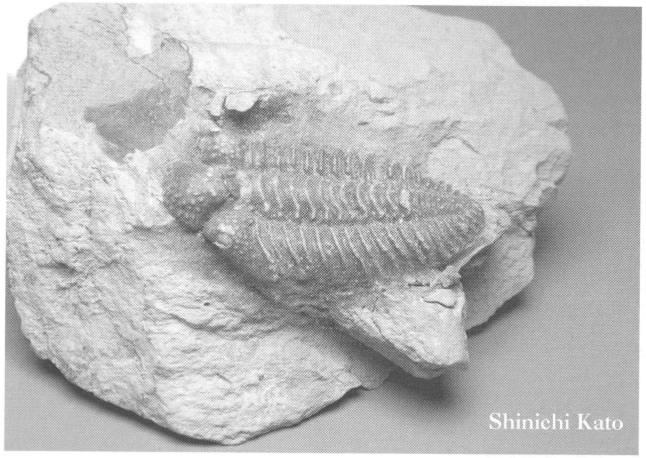


Rick Schrantz

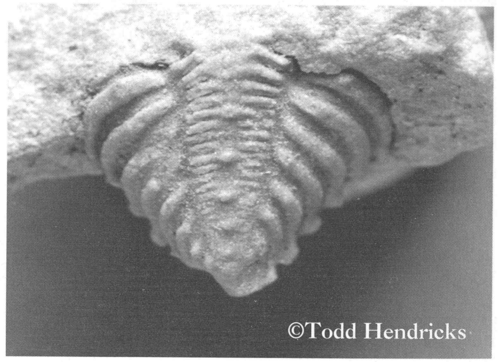
Incomplete *Dalmanites* cephalon, and a closeup of the eye.

Encrinurus Emmrich, 1844

Encrinurus is fairly rare.



Encrinurus.



Encrinurus pygidium.

Eophacops Delo, 1935

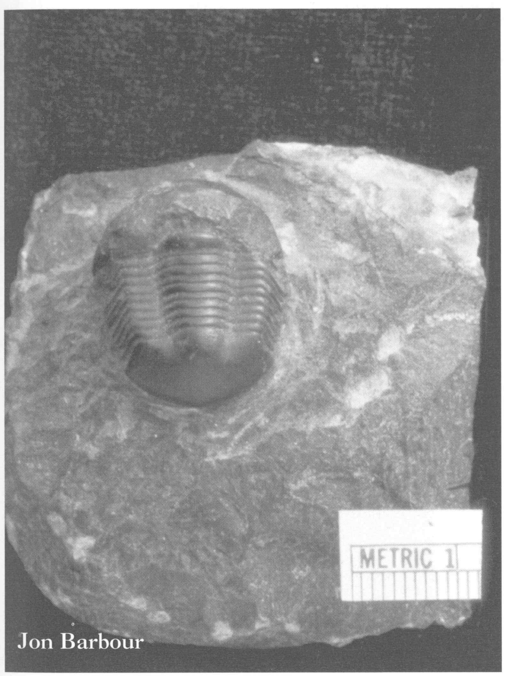
Eophacops is very rare.

Eophacops.

Gravicalymene Shirley, 1936

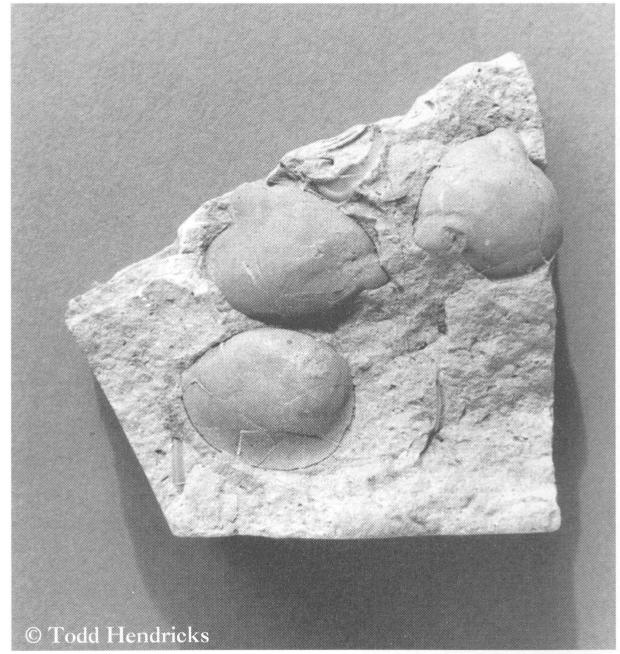
Pictured in Ordovician section.

Illaenus Dalman, 1827



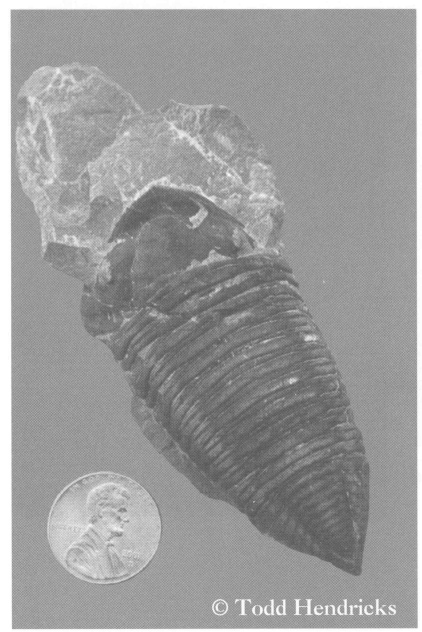
Illaenus americanus. YPM 19190. Courtesy of the Peabody Museum of Natural History, Yale University, New Haven, Conn.

Opsypharus Howells, 1982



Opsypharus (Howells, 1982).

Trimerus Green, 1832



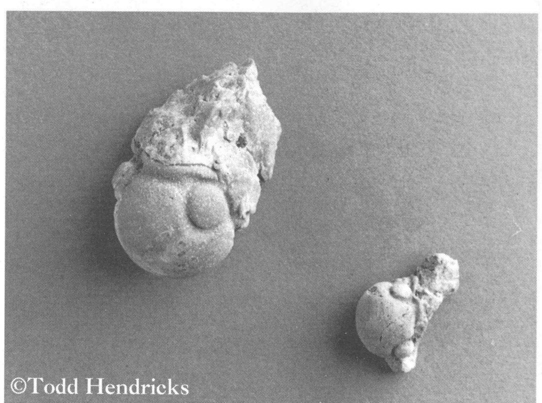
Trimerus.

Trochurus Beyrich, 1845

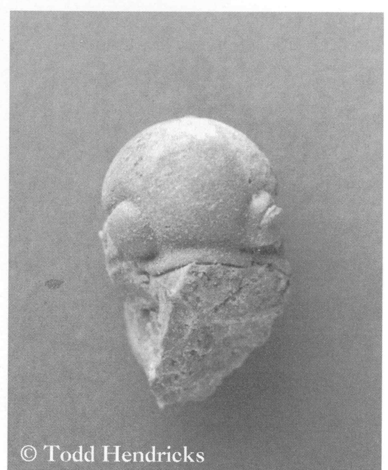
Trochurus is very rare; no complete ones are known in Kentucky.

Part of *Trochurus* cephalon.

Sphaerexochus Beyrich, 1845



Two *Sphaerexochus* cephala, and a closeup of the smaller one.



Devonian

Arctinurus Castelnau, 1843

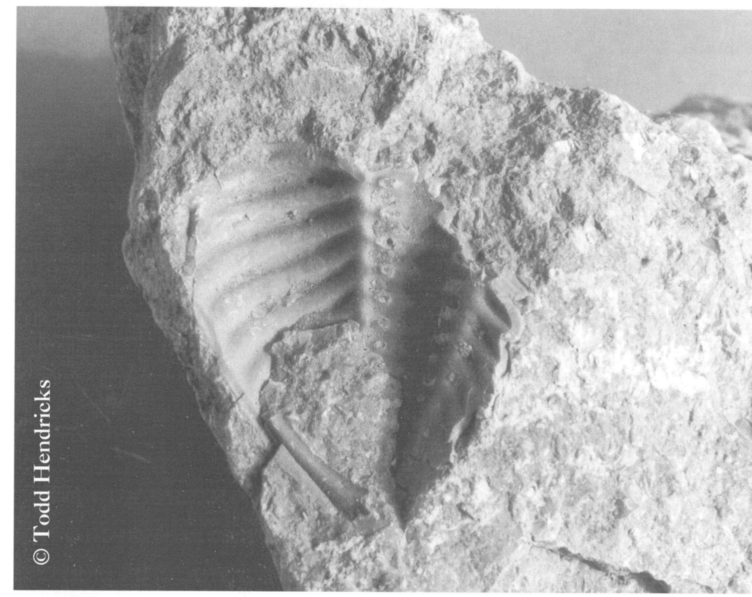
Pictured under Silurian section.

Calymene Brongniart, 1822

Pictured under Silurian section.

Coronura Hall and Clark, 1888

Coronura is fairly rare.



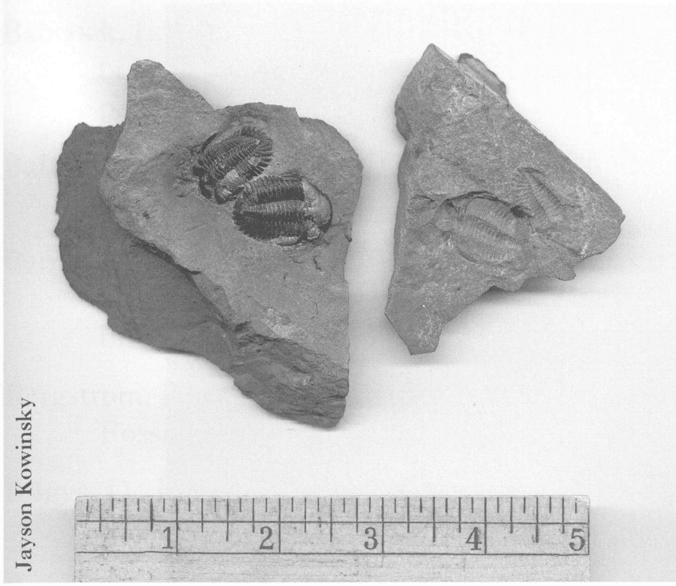
Coronura pygidium. This is the inside of the pygidium.

Dalmanites Barrande, 1852

Pictured under Silurian section.

Greenops Delo, 1935

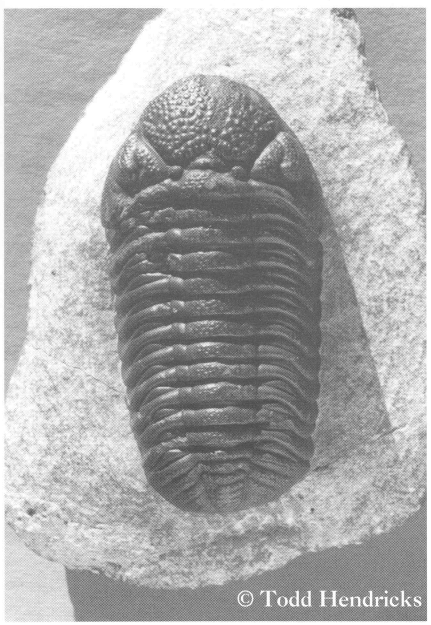
Greenops is fairly rare.



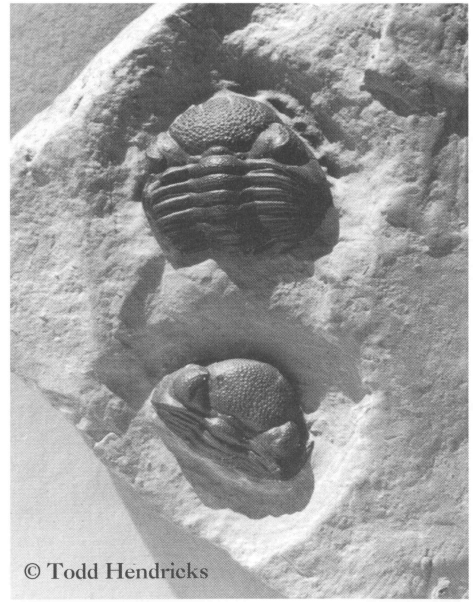
Greenops.

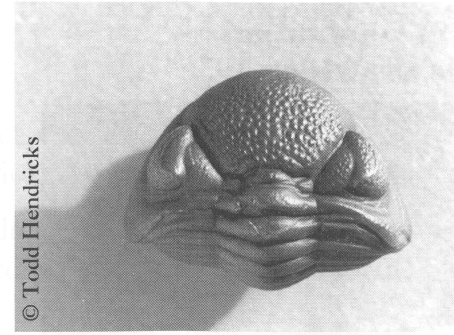
Phacops Emmrich, 1839

Phacops is scarce in some places, abundant in others.



Phacops.

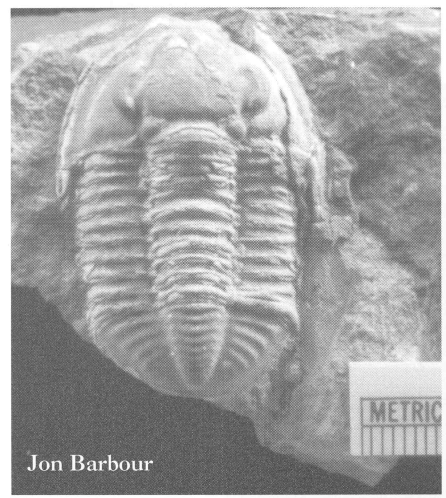




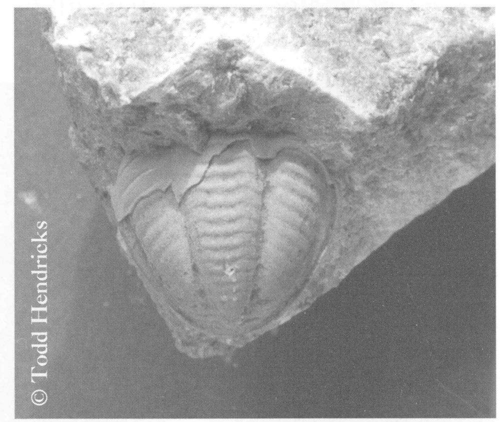
Phacopids enrolled.

Proetus Steininger, 1831

Proetus is scarce. Complete ones are very rare.



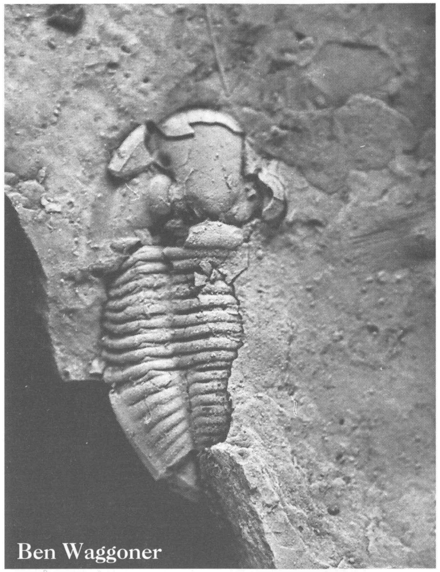
Proetus. YPM 6686. Courtesy of the Peabody Museum of Natural History, Yale University, New Haven, Conn.

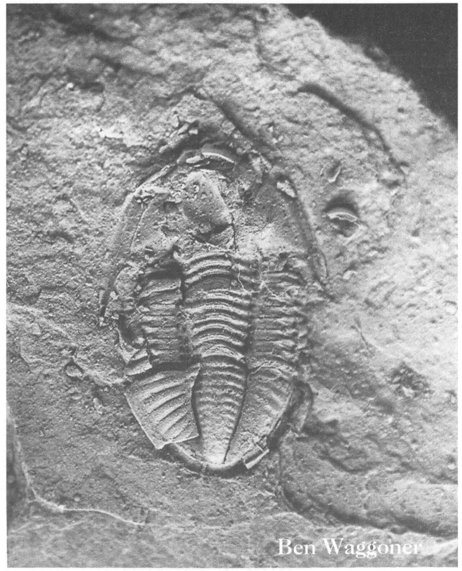


Proetus pygidium.

Mississippian

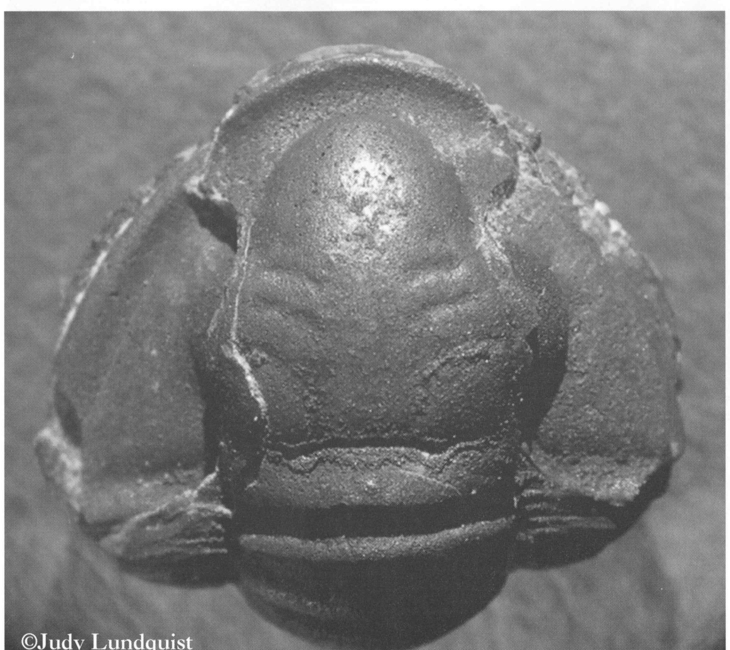
Paladin Weller, 1936





Paladin.

Piltonia



Piltonia enrolled.

Pennsylvanian

Ditomopyge Newell, 1931

Ditomopyge enrolled.

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Organizations

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Fax: (859) 257-1147

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2004 Sawyer Court
Lexington, KY 40514
(859) 296-4870

The Dry Dredgers (amateur paleontology association based in Cincinnati)
c/o Debby Scheid
2863 Hanois Court
Cincinnati, OH 45251

Some top Web sites for scientific information on trilobites

Kentucky Geological Survey
www.uky.edu/KGS

Kentucky Paleontological Society
www.uky.edu/OtherOrgs/KPS

Denman Institute for Research on Trilobites
www.island.net/~rolfl

The Dry Dredgers
homepages.uc.edu/~handgl/dredgers.htm

A Guide to the Orders of Trilobites
www.aloha.net/~smgon/ordersoftrilobites.htm

Kevin's TRILOBITE Home Page
www.ualberta.ca/~kbrett/Trilobites.html

Trilobites and Their Evolution through Time
www.brookes.ac.uk/geology/8361/1998/kirsty/trilo.html

Other interesting Web sites

Cincinnatian Trilobites
www.isotelus.com

Docfossil.com
www.docfossil.com

FossilGuy Web Page
www.fossilguy.com

House of Phacops
www.phacops.com

Invertebrate Paleontology Image Gallery (Peabody Museum of Natural History, Yale University)
www.yale.edu/ypmip

Kato's Collections
www.asahi-net.or.jp/~ug7s-ktu/english.htm

Paleontological Research Institution
www.priweb.org/collections/arth/tril/trilo_intro.html

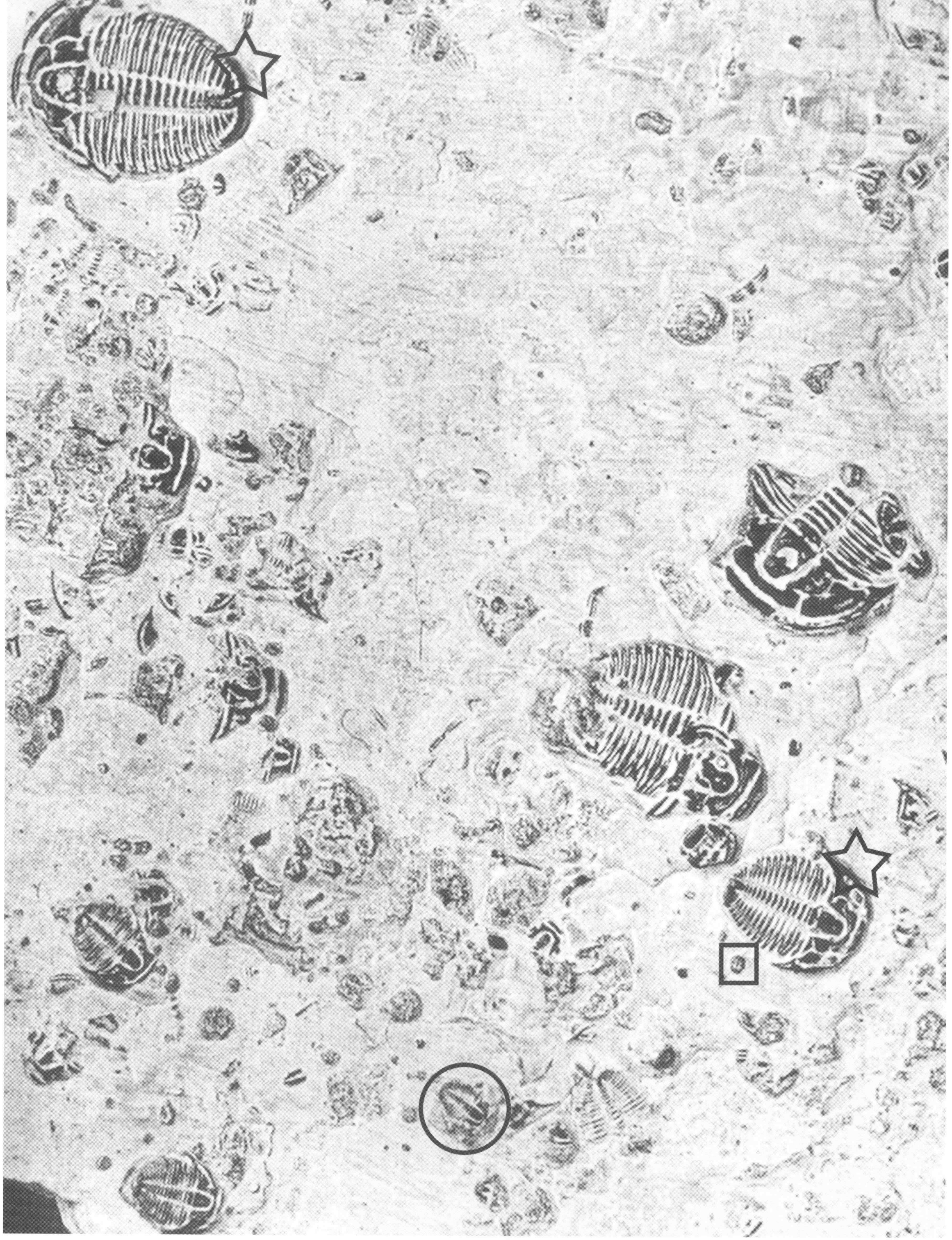
PALEOMAP Project
www.scotese.com

PaleoPlace.com
paleoplace.com

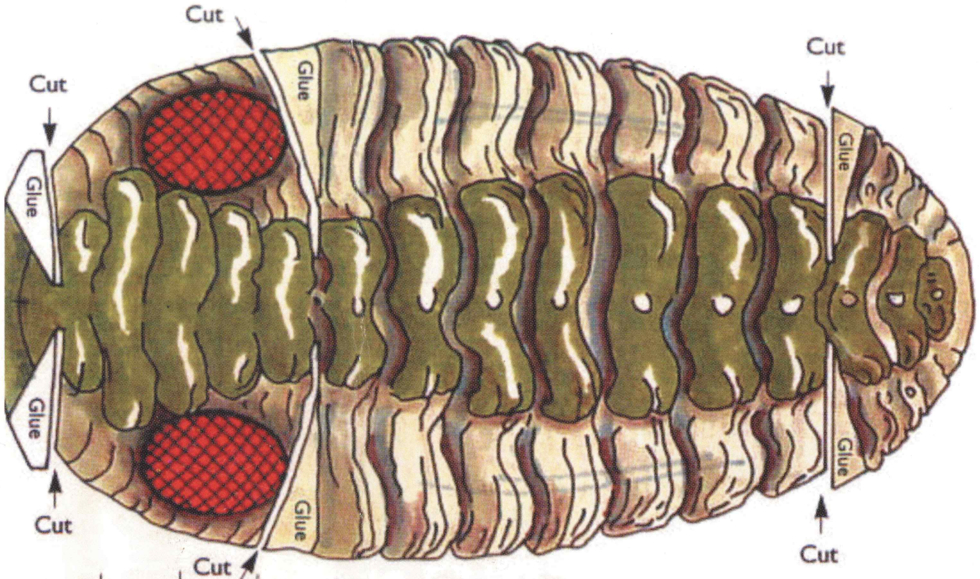
Primitive Worlds
www.primitiveworlds.com

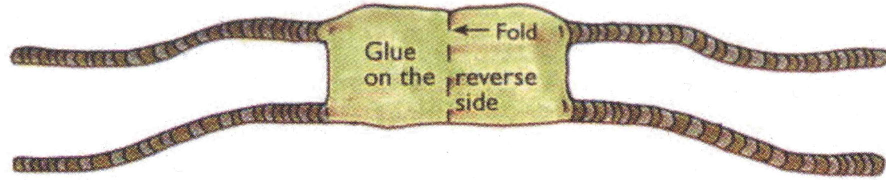
Trilobites.com
www.trilobites.com

The World's Biggest Trilobite
www.umanitoba.ca/academic/faculties/science/geological_sciences/stuff/geoaware/suletosi

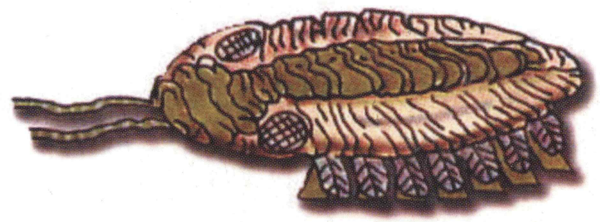


☆ Holaspid ○ Meraspid □ Protaspid

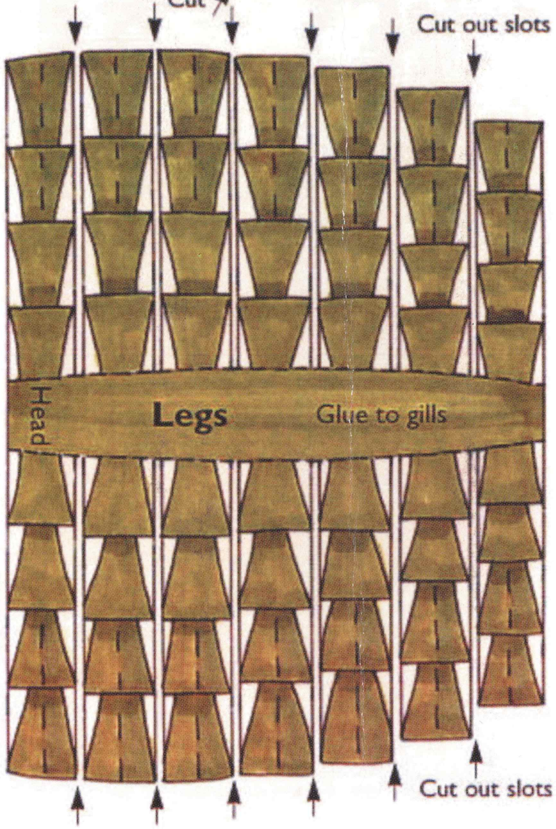


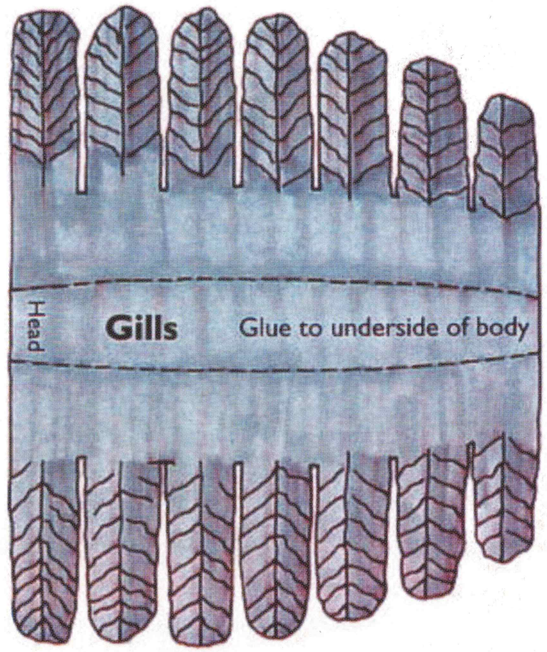


Trilobite Model



Completed model Trilobite





1. Cut out the trilobite's body, gills and legs.
2. Fold along the dotted lines.
3. Glue gills to underside of trilobite's body.
4. Glue legs to underside of trilobite's gills.
5. Glue antennae to underside of head.

Trilobite model by Australian Geological Survey Organisation, Geoscience Awareness Unit (Phone (02) 62499492), produced in association with the U.S. Geological Survey, Open-File Report 94-667, by Tau Rho Alpha.