American Scientist Interviews: Paul Olsen on dinosaurs, asteroids, and narratives in earthhistory
Keith Wailoo and Paul Olsen
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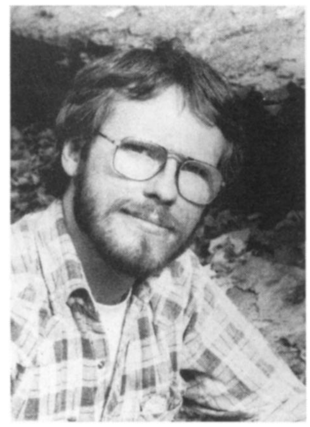


Paul Olsen

Paul Olsen's interest in rocks and fossils was kindled early. At the age of 14 he gained local acclaim when he and a friend, while walking through a quarry near his home in New Jersey, stumbled on the footprints of a dinosaur. Twenty years later, the quarry is preserved as Walter Kidde Dinosaur Park, and Olsen, paleontologist and assistant professor of geology at Columbia University's Lamont-Doherty Geological Observatory, has continued his search for Mesozoic life on favorite rock outcrops beside the Lincoln Tunnel, near the George Washington Bridge, and beneath cliffs overlooking the Bay of Fundy in Nova Scotia. In 1985 Olsen again stepped into the limelight of discovery, this time with colleague Neil Shubin, then at Harvard. Scanning the cliffs at the Bay of Fundy, the two men located a trove of over 100,000 fossils that reveals a vast extinction some 200 million years ago and lends support to the theory of catastrophic change in natural history.

The assemblage is the first glimpse of life at the Triassic-Jurassic boundary, and it shows an abrupt decline in the diversity of life at that time. Olsen, at 34 considered one of the leading experts on the period, believes that not only is this the record of an actual large-scale extinction but it is the first time that such an event can be linked to the known impact of an asteroid, which left a huge crater some 800 km northwest of the find. Olsen recently spent an afternoon on the Columbia campus discussing the geological and philosophical implications of his find. An amateur painter and a student of history, he also offered some thoughts on the relevance of narrative and creativity to his world view as a modern paleontologist.

You have an undergraduate degree in geology and a Ph.D. in biology. Is that typical training for a paleontologist?

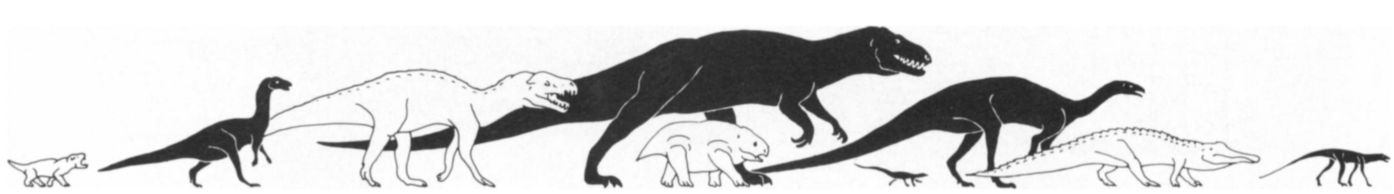
I don't consider paleontology to be a real field, a real natural division of subjects. It's just the biology of dead things—or fossils as rocks, depending on your point of view. The biological perspective is useful if you're looking at the organisms; however, as a paleontologist you could use the fossils just as environmental indicators, or perhaps as time guides—tools to understanding the geology—and in that case you wouldn't necessarily need the biological input. Nonetheless, the study of fossils does yield a unique biological perspective that we can never get from studying only the living world. The crucial time dimension is what makes paleontology worth doing in the first place.

In general, my overriding interest is the evolution of ecosystems, especially lakes. My Ph.D. work was on how individual elements of the lake ecosystem evolve through time, how new species evolve, how they fill up niche space, and also how energy flows within the ecosystem. In my thesis, I dealt principally with lakes because they are nice, closed systems that are relatively easy to understand. The rocks I focused on were in the chain of rift valleys that goes from Nova Scotia to South Carolina, the so-called Newark Supergroup. The water in the lake basins among these rocks existed on and off for over 45 million years of sedimentation.

Does this mean the lakes themselves grew and shrank in the course of time?

That's right. A lake will fill and recede with changes in climate from humid to arid, and this represents a big change to the lake ecosystem. The frequency of climate change in the Late Triassic was around 21,000 years: the lake comes and goes, with fish developing within the lake when it's new and going extinct when it shrinks. So you have animals evolving and going extinct, evolving and going extinct. But when you look at the record of all these lakes piled on top of one another, contrary to what you might expect you find very little change, or else very slow change.

But while I was working on this ecosystem change in the Newark Supergroup, I began to see an event which was completely different from the slow, background change. This was a



very large extinction that was recorded in these sediments, an event in which something like 43 percent of all families of terrestrial and lacustrine (lake-dwelling) vertebrates died out. There's more change within that mass extinction than in all the accumulated change of, say, 30 million years.

How do you recognize a mass extinction in the fossil record?

Well, the thing that's remarkable about the assemblage in the Bay of Fundy is that even though we have something on the order of 100,000 bones, the forms characteristic of the Late Triassic are completely absent. The crocodile-like phytosaurs, or four-legged plant-eaters such as the aetosaurs, with their covering of armor—a bunch of creatures that had a long pedigree before the Jurassic—are definitely absent from this find. And we have confidence that that lack means something, because within the Nova Scotia finds we have a whole suite of different environments represented—aquatic, fully terrestrial, hillside, valley, stream—and in all these environments, the Late Triassic animals are missing. But all the animals that *are* present in the find are also known from the Late Triassic.

Now that's very interesting, because if you had a hypothesis that what caused the extinction of those other Triassic animals was the evolution of new forms—of superior competitors, for example—then you would not expect to see those competitive groups living side by side for millions of years. Yet that's exactly what you do see in the Late Triassic: the organisms that were to survive and those that didn't survive were living together for millions of years, and then—boom!—you get to the Triassic-Jurassic boundary and half of them are gone; and the other half just go tooling along and don't change much.

If the other half had changed, that might indicate that there were competitive interactions. The fact that this Early Jurassic assemblage consists of survivors without any new arrivals strongly suggests that something unique happened, like an asteroid impact, which wiped out those other forms.

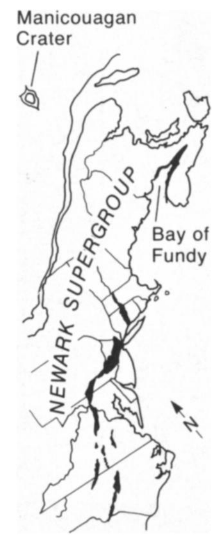
Is this kind of hypothesis something that you, as a paleontologist, take with you into the field, or is it something you let the fossils dictate?

I don't believe that any scientist uses pure methods of induction in looking at the world. Even our normal vision requires our mind to have a model of the world in order to perceive it. But I like to take it a step further; I like to have at least one central hypothesis guiding what observations I choose to make, to help me focus on a particular problem. The geological world, like the rest of the natural world, is infinite, and you could collect observations forever and they wouldn't mean anything at all. You need some theory to focus data collection, and then you need to see whether the theory corresponds to reality or not. The Nova Scotia find seems to indicate that the extinctions are indeed concentrated within one short interval of time, and Neil Shubin and I think that the interval was less than a million years. But what we want to do now is test that hypothesis; we want to look more closely at the Triassic-Jurassic boundary and see how the distribution of organisms, as measured by climate cycles, really documents the rate of change.

What is the distinction between Triassic and Jurassic?

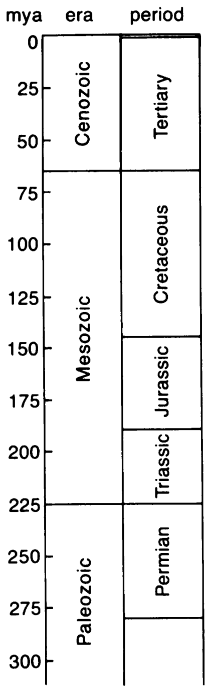
It's something like the difference between Tuesday and Wednesday. It's an arbitrary division of time. When geologists looked at rocks in Europe and saw a break between the continental and the marine rocks, they called the rocks below the break Triassic and the rocks above it Jurassic. As it turns out, there are a lot of things that go on at that boundary, but you could say that we have defined time arbitrarily as divided into those periods.

Next it was recognized that some of these rocks we were calling Late Triassic were in fact Early Jurassic. That meant that what was thought to be an absence of terrestrial vertebrate fossils in Early Jurassic rocks around the world was in fact an artifact of giving the wrong date to rocks that were actually Early Jurassic in age. When you recognize the fact



In cliffs along the Bay of Fundy, in Nova Scotia, the Triassic-Jurassic boundary is visible just below the white layer. (Photo by P. Olsen.)

that there were those Early Jurassic-age terrestrial rocks, it stretched out the age of all the fossils in those rocks. And the mass extinction became smaller just because of that. Then what happened was that people started looking much more closely at Late Triassic and Early Jurassic rocks, and they began to find that some forms that were thought to go extinct early in the Late Triassic actually made it to the very end of the Triassic. And so they began again to condense the ranges, and what became evident looked like a short period of many extinctions.

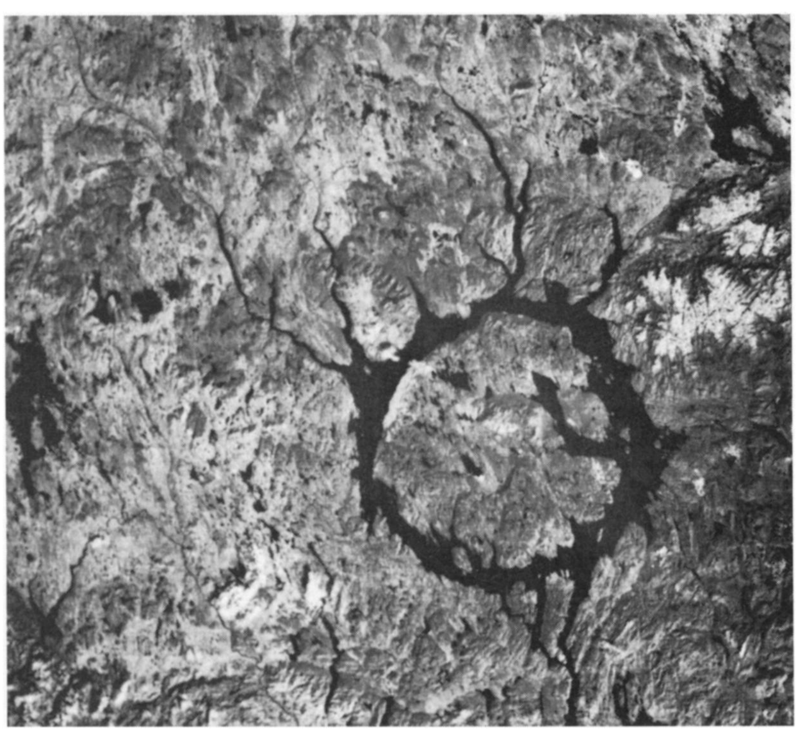


There's been a long and continuing debate between gradualists and catastrophists in geology. But it seems that scientists are talking more about catastrophic change now than, say, 30 years ago. Why do you think that's the case?

It's always difficult to talk about catastrophic versus gradual change, because one man's gradual is another's catastrophic. The way we view a change is dependent on the time scale, on how long a period of time the extinction took to occur. And in fact, many of the debates of catastrophism versus gradualism are actually debates about the time scale.

However, there's no question that 30 years ago these ideas about asteroid impact or very fast evolutionary changes would have been regarded as simply heretical, because in most geological cases it's easier to prove that something happened gradually than that it happened suddenly or catastrophically. Something that looks catastrophic in the geological record can be due to no more than the fact that sediment was not deposited during that time. That will make a jump, obviously, in the rock record. But a long series of events that are spaced out nice and equal, with slow change between two points—that's impossible to produce by accident, and thus it's clear evidence for gradualism. If you think about it, the world as we see it has both gradual and catastrophic events occurring.

But also, I think the willingness to look at catastrophic change has to do with the number of revolutions we've seen in our own lives, the very drastic changes in governments and wars. And certainly the idea of nuclear annihilation has contributed to this. On the other hand, we can hope that part of it is due to actually observing and developing new hypotheses about the way nature operates. For instance, we didn't even know how to describe a catastrophe mathematically before; now there's a whole branch of mathematical theory that deals with this.



The Manicouagan crater, 70 km in diameter, was created about 200 million years ago when an asteroid struck the earth with tremendous force. In this satellite image, the waters of a present-day reservoir (black areas) define the outline of the crater. (NASA ERTS photograph, courtesy of the Planetary Image Center.)

You postulate that the mass extinctions of the Triassic-Jurassic boundary resulted from an asteroid that struck the earth with tremendous force 200 million years ago. How does this explanation differ from the theory that an asteroid impact caused the extinction of the dinosaurs at the Cretaceous-Tertiary boundary, 65 million years ago?

The Cretaceous-Tertiary boundary has a big problem. It doesn't have direct geological evidence of an asteroid impact—in other words, a crater. (There are many reasons that this evidence might not have been preserved, such as subduction or erosion.) But the Cretaceous-Tertiary boundary does have that sharp anomaly in levels of iridium, for which a variety of explanations are possible. One is, indeed, an asteroid impact; another is widespread volcanism involving deep-seated magma of a type that doesn't exist in the world right at this moment. There are other possible explanations, too, but none is conclusive.

By contrast, what we have in the Triassic-Jurassic is a smoking gun. We have unmistakable evidence of an asteroid impact, in the form of the huge Manicouagan crater, northwest of the find at the Bay of Fundy. We can ask the simple question, "What were the biological consequences of that particular asteroid impact?" To do that, of course, we must be able to identify, very precisely, some record of that impact in the sediment in which we find the fossils. We haven't done this yet, and I must stress that the idea for this step belongs to

Mark Anders, at Berkeley, a student of Walter Alvarez.

Can you describe the difference in taxonomic recovery between the Triassic-Jurassic and the Cretaceous-Tertiary boundaries? Do the different speciation patterns after these supposed extinctions tell us something about, say, the rise of mammals?

There is a big difference in rates of taxonomic recovery. Of course, the Cretaceous-Tertiary boundary is known in much more detail than we know the Triassic-Jurassic boundary, so we immediately have flags of caution go up as to

This fossil from the Late Triassic preserves in unusually fine detail the footprint known as *Rhynchosauroides hyperbates*, made by a lizard-like reptile that became extinct at the Triassic-Jurassic boundary. (Photo by P. Olsen.)

whether we can make a comparison at all. But if you take the evidence as it stands right now, within 10 to 20 million years of the Cretaceous-Tertiary boundary the world was covered by an enormously diverse suite of mammals. The full taxonomic richness of the Cretaceous was already recovered and exceeded by that time. However, when you look 10 million or 20 or even 40 million years after the Triassic-Jurassic boundary, you're nowhere near the level of diversity that you saw in the Late Triassic. The recovery was very slow compared to that after the Cretaceous-Tertiary boundary. Of course, different groups of organisms were dominant. In both cases, mammals survived the boundaries. Mammals were already present at the Triassic-Jurassic boundary and made it through. However, they never did much during the Mesozoic. Mammals remained at a relatively low diversity and sort of hidden in the underbrush while dinosaurs were the dominant creatures on land. And dinosaurs, while perhaps being numerically dominant, don't seem to have had the same types of breeding strategies, or perhaps they don't show the differences between species as well. Their taxonomic diversity never seems to approach that of mammals, even though they had plenty of time to do it in. And yet one group of dinosaurs, the birds, which also survived the Cretaceous-Tertiary boundary, are very diverse—much more so than the other dinosaurs.

Would that have anything to do with the mobility of birds, as compared to other animals?

That's possible, birds are highly mobile. But so were dinosaurs; dinosaurs were really specialists at moving around, almost like modern ungulates. One of the interesting debates that's going on now is whether or not dinosaurs could survive cold climates, or survive the six months of darkness that would occur at the poles. And when we think about it, most dinosaurs could probably have walked away from that. Every six months they may have migrated from north to south. We just don't know, they certainly look like they were pretty mobile animals.

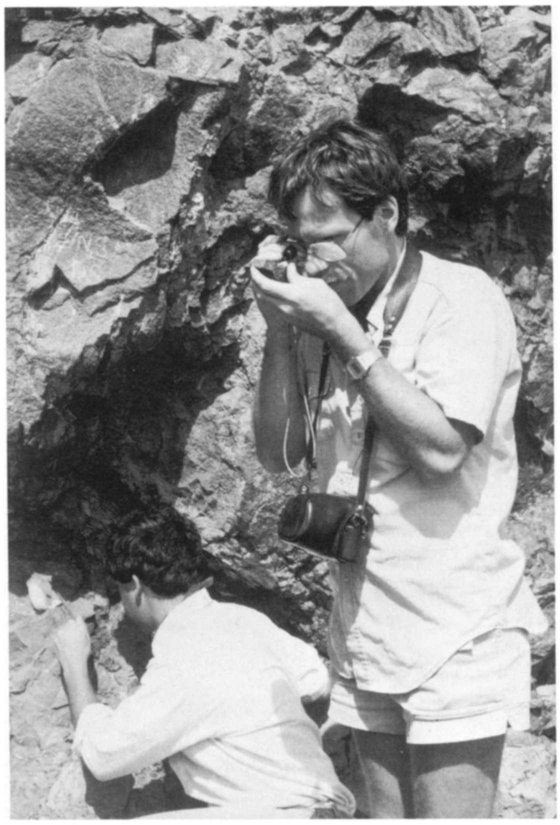
Is there any fossil evidence for this?

Well, there's no evidence that they actually migrated—although the provinciality of dinosaurs is very low, and that might suggest that they got around a lot. Dinosaurs look very similar from place to place, as a rule. Bob Bakker, for example, has proposed that most dinosaur herbivores migrated from place to place in search of food and covered enormous distances, just as elephants will cover great distances in a single year, or antelopes or any kind of modern ungulate.

Does this mean that the extinction of dinosaurs after the Cretaceous-Tertiary boundary opened up a sort of vacuum that allowed for the rise of mammals?

The mammals were already doing a little diversification in the Late Cretaceous, but they really did go wild after the extinction of the dinosaurs, no question about it. Within a few million years there were already great big Tertiary animals—things the size of cows. Actually, the mammals almost didn't make it, because no sooner did the dinosaurs become extinct than some ground birds started to

1978: B.A. (Geology), Yale University
1984: Ph.D. (Biology), Yale University
1983: Miller postdoctoral fellowship, University of California, Berkeley
1984: Assistant Professor of Geology, Lamont-Doherty Geological Observatory, Columbia University



Olsen, standing, takes a closer look at bones of a fossil crocodile, while colleague Neil Shubin examines the cliff face. (Courtesy of Tom Lunde/*Columbia Magazine*.)

become very predatory, and got to be very large. They were basically armless dinosaurs, and for a while they were the dominant carnivores. And every so often during the age of mammals, you had birds being the dominant carnivores. They're still very powerful carnivores today.

Going back to the Triassic-Jurassic boundary, what's the size of the Manicouagan crater and the magnitude of the asteroid impact?

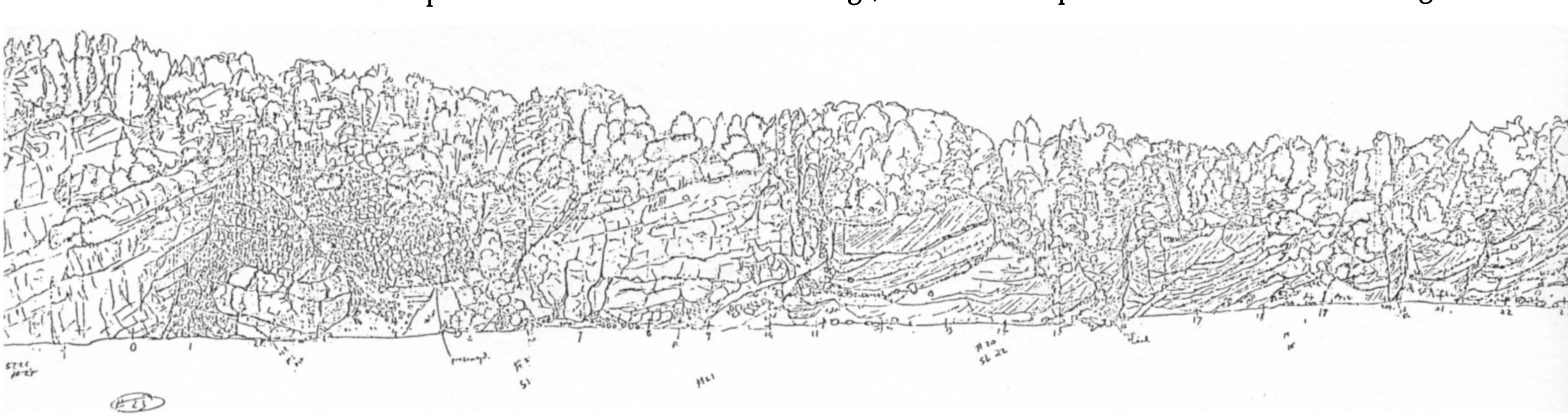
The preserved crater, as it looks right now, is about 70 km in diameter. It's thought to have been produced by an asteroid 6 to 7 km in diameter, traveling at about 25 km per second. The impact released about 10^{29} to 10^{30} ergs, which is roughly 100 million megatons (a megaton is getting up to the size of our larger nuclear weapons). In terms of power, the Manicouagan impact would be roughly 10,000 times the combined nuclear arsenal of the Soviet Union and the United States. The fireball that would come from such an impact might be 2,300 km in diameter—that's the diameter of the zone around the crater where everything on the surface would be killed—and there was a shock wave outside that which probably killed quite a bit. The magnitude is unthinkably large.

In a recent paper, you note that an attractive characteristic of the asteroid impact theory of extinction is that it can be easily falsified. Why is this important?

Within paleontological theories, especially, there's a tendency to make the stories fit the available data. But nothing is more useless than a hypothesis that can never be shown to be wrong. For example, the hypothesis that species A ate species B ate species C might be made on the basis of the size of the animals and the fact that two are carnivorous and one is not. Yet it's very hard to show that one form *never* ate another—in other words, to show that a specific event did *not* take place. So, even if you have a nice, consistent story, what you could learn from that story is minimal, because it doesn't rule out any other possibilities. But in the case of the impact theory, the only way it can be corroborated is if the extinctions and the cause of the extinctions fall exactly at the same time. It won't do for the extinctions to occur before the event and it won't do for them to occur a long time after the event.

You have also suggested in a paper or two that scientific theories are not divorced from social norms. What makes it easier for a geologist to observe that than, say, a chemist?

Geologists, paleontologists, cosmologists, and biologists are always making stories about the world. Part of our goal is to understand a historical sequence of events. We're making a



narrative, and it's hard to avoid bringing our own prejudices into the picture. You see it again and again within the history of biology and the social sciences and geology; Steve Gould has documented quite a bit of this. The sorts of models that we construct of the world infiltrate all our ways of thinking.

You mentioned narrative. What is the value of narrative in, for example, geology?

One responsibility of a good geologist and paleontologist is to bring the past to life for other people. I think part of the fascination that children have for paleontology, and especially for dinosaurs, is playing on that "fantasy" world that was real. We had monsters back then!—or things we would view today as monsters. And the more we can bring that element to life and let other people look at it, the better off we are as scientists. Often people will say, "The extinction of the dinosaurs sounds like a nice story, but what on earth does it have to tell us about the modern world?" Well, of course, it was an attempt to explain the history of the dinosaurs that gave us the nuclear winter hypothesis. Whether the hypothesis is a correct assessment of the effects of nuclear war is not as important as the fact that it has forced us to reassess the global effects of a nuclear war. The relevance of a particular scientific theory is not always apparent right away.

Let's return to the site of your work, the Bay of Fundy. Can you describe the setting and the steps you take to analyze what must be a very complex formation?

The site has three parts: the cliff, the highland above the cliff, and the tidal flat below. The tidal flat is a mapper's paradise, because there's only a few inches of mud on it, and underneath there's flat rock. It's a perfect horizontal cross section, a perfect map. Then, when you hit the cliff, you make a vertical map. The cliff plus the tidal flat gives you two good sections from which to reconstruct the three-dimensional relationships of a lot of the rocks you see. And once you have the three-dimensional relationships, you can start understanding the history of the movement of those pieces of the geometric puzzle.

I've been working in the Bay of Fundy since 1970, and it's taken me a long time to understand what's going on there. When you look at those rocks you're bombarded by an enormous range of features—cracks in the rocks, boulders, small faults, large faults—and it's very difficult to understand what is important in a large-scale geometry that you can never see completely. You can only infer it, make a mental map or a physical map, and to do that you must filter out the extraneous information. What we finally had to do was draw on a scale of one-quarter inch for ten feet, which gave us an enormously detailed map of a two-mile region.

Does your work as an artist—your painting, sketching, and etching—open up new avenues of thought on your work as a paleontologist? Does it derive from your scientific interests?

I think my art has a completely independent life. It has always dealt with relatively mundane scenes: city scenes, factories, meat markets. I can't say that it springs out of any particular aspect of my research, or that I take a falsifiable view of my painting. I think it's purely expressive and emotional, and divorced from my science.

I do get a very big kick out of doing science, as well. In fact, there are very few things I find as rewarding as a new idea that turns something very chaotic or noisy into some clear form; that gives me a thrill. When that flash of realization has occurred, all of a sudden you see the world in a completely new way and it really looks different. Its physical nature seems to have changed. For that, it's essential to have an active imagination, and as long as it's constrained by reality you're probably better off in general.

In a continuing series of interviews with young scientists, science writer Keith Wailoo talked with Paul Olsen for American Scientist.

Essential for a focused paleontological excavation is a detailed sketch of the site that highlights geological features. Shown below, greatly reduced in size, is a section of the original sketch, which measures over 7 m long. (Sketch by P. Olsen and R. Schlische.)