Science Fact

Fish Kill on the Tanis: What an Ancient Piscine Boneyard Tells of the Day the Dinos Died

Richard A. Lovett

"Spring is the time of plans and projects," Leo Tolstoy wrote in Anna Karenina. But if you were a Northern Hemisphere dinosaur at the end of the Cretaceous Period, there was one spring when those plans and projects would have been remarkably short-lived. Because, amazingly, scientists have found evidence that the dinosaurs died not in winter, fall, or summer. They died in the springtime. "My guess is on April," says Melanie During, a vertebrate paleontologist at Uppsala University, Uppsala, Sweden, whose findings appeared in *Nature* on February 23, 2022.[1]

We all know the basic story. Sometime around 66 million years ago, a ten-kilometer-wide asteroid or comet smashed into what is now Mexico's Yucatan Peninsula. The Chicxulub impact, as it is called, blew out a 150-kilometer-wide crater and ejected massive amounts of debris into the upper atmosphere. There, joined by smoke from wildfires ignited by the blast, the dust lingered, blocking sunlight and plunging the Earth into an extended cold spell, akin to the nuclear winter feared from global thermonuclear war. Before it was over, not only were the dinosaurs gone, but so too were three-quarters of the Earth's other animal species and nearly 50% of the Northern Hemisphere plant species. (Southern Hemisphere plants fared better.)

It's called the K-T extinction because it marks the boundary between the end of the Cretaceous Period (not the only geologic period starting with the letter "C," hence the use of the

“K”), and the start of Tertiary Period, which followed. Other factors may have contributed—most notably massive vulcanism in India’s Deccan Traps volcanic region, but most scientists believe the Chicxulub impact was the death blow.

Trying to determine exactly when that impact occurred has been a continuing quest, largely based on high-precision measurements of radioisotopes in rocks formed before and after the impact. The best guess, published in *Science* by a team led by Paul Renne, a geochronologist at the University of California, Berkeley, is that the impact occurred 66,038,000 years ago, plus or minus about 11,000 years.[2] But there’s a big difference between “plus or minus 11,000 years” and “April.” Not that During is trying to pinpoint the dinos’ demise to a single April in Renne’s 22,000-year window. What she’s saying is that wherever it was in that range, it most likely occurred in the Northern Hemisphere spring . . . and fairly early on in that spring, at that. But it’s still a rather extraordinary claim.

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Ancient River

The tale begins in 2008, when paleontologists discovered a fossil-rich promontory in the badlands of southwestern North Dakota, about one hundred miles from the more famous badlands of Theodore Roosevelt National Park. (The exact location is a closely guarded secret.)

Excavation proceeded slowly, but in the spring of 2017, During was at a conference where Jan Smit, a sedimentologist at Vrije Universiteit Amsterdam, Netherlands, unveiled what he and his colleagues had found. Even before he had finished talking, During says she was typing an email to him “from the back of the room,” asking if she could have access to the site. A few months later she was in North Dakota, stunned both by the 104° heat and what she saw.

What Smit and his colleague Robert DePalma (then a graduate student at the University of Kansas) had found were the remnants of a fish kill that must have occurred in the immediate aftermath of the Chicxulub impact. How soon after wasn’t yet known, but what During saw was dramatic.

The rock strata, named the Tanis deposit (presumably in honor of an ancient Egyptian city buried in silt), appeared to have originated as a sandbar on a river (now called the Tanis River). When the Chicxulub impact occurred, the area was struck by an earthquake larger than anything in recorded history (some reports put it at magnitude ten or even magnitude 12).

Even though the Tanis was 3,500 kilometers from the impact site, the earthquake created what seismologists call a “seiche”—a violent sloshing motion, akin to what an exuberant child might create in a bathtub. That sent walls of water at least ten meters high rushing upstream and downstream, stirring up massive amounts of sediment. Simultaneously, BB-sized glass spherules, called tektites, were falling from the sky: molten rock splashed into space by the impact, now raining back to Earth.

“They look like small glassy spheres, comparable to obsidian,” says Jeroen van der Lubbe, a paleontologist at Vrije Universiteit Amsterdam. Within minutes, uncounted numbers of fish were buried alive . . . with hundreds of them winding up atop the one-time sandbar.

For the fish, it was a catastrophe. In one layer, they were facing downstream as they vainly fought against a surge coming from that direction. In the next, they were facing upstream as they fought against a return surge. Some had been hurled around so violently that their bodies were broken and wrapped around tree limbs. “It looks like the worst car crash you have ever seen, frozen in place,” During says. For the paleontologists, though, the fishes’ catastrophe was a goldmine. “It was the most spectacular deposit I have ever seen,” During says.

Her first task was to collect samples and return them to the lab for analysis—a task complicated not just because of the stunning heat and fear of rattlesnakes, but the fact that the fossils were entombed in badland clay that didn’t react well to being dug up, forcing During to work more quickly than paleontologists normally like to work. “Once the sun got on it, it would shrink and dislocate everything,” she says.

Not to mention that there were so many fossils that the attempt to extract one might reveal another, uncomfortably close to it. And because no paleontologist wants to ruin one fossil while trying to extract its neighbor, During says, “there was this problem of, ‘Oh, now another fish.’”

From a published paper by Robert DePalma and others. The individual authors responsible for each specific image or diagram in the paper are not individually stated—https://creativecommons.org/licenses/by-sa/4.0/

Ultimately, however, she got six intact specimens back to Europe. Three were paddlefish. Three were sturgeon.

One of the first things her team then did was to examine them carefully, finding that the fish had died with tektites in their gills. That meant the tektites were already in the water at the time of their deaths. But none of the fish appeared to have had tektites in their digestive tracts, meaning they couldn't have had time to accidentally swallow any of them before they died. And since paddlefish and sturgeon are filter feeders, living off plankton and related food sources, that meant there hadn't been a lot of time between when the tektites first hit the water and when the fish died.

That is important, During says, because tektites would have started falling back to Earth fifteen to thirty minutes after the impact. The shock waves that created the seiche would have hit the Tanis at about the same time, speeding through the Earth's crust at about 3.5 kilometers per second (7,600 miles per hour).

There are, of course, other things that can cause fish kills, such as viruses, toxic algae, or rapid changes in dissolved oxygen. But this couldn't have been from one of those, because even if you ignore the tektites and the seiche, the Tanis River fish kill is overlain by a thin layer of iridium-rich sediment.

Iridium is a metal that is rare on Earth but appears to have been much more common in the Chicxulub asteroid. When the immediate effects of the impact abated, that iridium settled out of Earth's atmosphere to form an iridium-containing layer draping the entire planet. The fact that this layer lies immediately above the Tanis River fish, provides conclusive proof that it was the Chicxulub impact that killed them, not some unrelated catastrophe. "There is nothing that happened between these fishes dying and the iridium deposit," During says. "It has to be within the hour."

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Growth Rings

That established, the next step was to see what more the fossils could reveal. And, it turned out, that was a lot.

The bones of paddlefish and sturgeon are known to grow in annual cycles: slowly in winter, and more quickly in spring. One way to detect these cycles is by taking tiny slices of the preserved bones and looking at the ratio of carbon and oxygen isotopes in their minerals. These vary with the availability of the fishes' primary food supply, plankton, and show a distinct cyclical pattern that reflects the change in plankton availability throughout the year: high in summer, low in winter. It's a bit like looking at growth rings in trees.

Sixty-six million years ago, that part of North Dakota was a bit farther north than it is now—more like modern-day Calgary, Alberta. That's far enough north for it to have had four very distinct seasons, even at a time when the global average was warmer than today. Winter lows, During says, tended to hit about 41°F. Summer lows tended to average around 66°F to 68°F. That, combined with seasonal changes in sunlight, would have been a large-enough variation to have a substantial effect on the amount of plankton in the water in any given part of the year, strongly affecting the fishes' diet.

The fish collected by During were seven to nine years old, meaning that their bones preserved seven to nine such cycles. And when van der Lubbe measured the isotope ratios in the bones, those in final layers, just before the fish died, showed that plankton were rebounding but hadn't yet reached peak abundance. Not winter. Not full summer. Spring.

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Support for this came from a second analysis using high-energy X-rays generated in a particle accelerator known as a synchrotron.

Dennis Voeten is a vertebrate paleontologist at Uppsala University who specializes in using such radiation to do 3D scans of the interior of fossils. You could think of it as doing a CT scan on a rock, except that these scans can be done at amazingly fine scales. (Other researchers have used synchrotron radiation to image softer materials, like entire mouse brains, at the cellular or even subcellular level.[3])

The first thing Voeten found when he scanned the fish was that there were indeed no tektites in their digestive tracts: confirmation that the fish had died immediately after the Chicxulub impact. Then he dug deeper, looking at another aspect of the growth cycles of the bones, which is that they grow faster in summer than in winter. This, he says, is reflected in the size of each new layer of bone cells. Big cells mean fast growth; small cells mean slow growth. Not that fossils still contain cells. But, Voeten says, "we can see the holes in which bone cells were once located."

Again, it was possible to trace this pattern over the entire seven to nine years of the fishes' lives: larger, smaller, larger, smaller, larger, smaller, until the end when, Voeten says, the cells were relatively small, but starting to get larger. I.e., spring. And it wasn't just at the very earliest beginning of spring, says During, but a bit later than that. Hence her best guess of April. "More accuracy than this is not reachable," she says. "But it was definitely not summer."

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Leaf Miners and Mayfiles

During's work is supported by a second study published two months earlier by a team headed by DePalma (now at Florida Atlantic University, Boca Raton, Florida).

The earlier publication date makes it sound like principal credit for this discovery should go to DePalma's team, but that's not how science works, because During's team submitted its study to *Nature* almost ten weeks before DePalma's team submitted its results to another journal, *Scientific Reports*. The fact that *Nature* took longer to get During's article into print doesn't deprive her of first claim on the discovery.

That said, the two studies very much support each other. DePalma's group came largely to the same conclusions as During's, though they were less precise about the date, pegging fishes' deaths to sometime "likely to have been [in] the Spring and Summer months."[4] In the process, however, they added two more lines of confirmation to those found by During's group.

The first came from fossil leaves swept up in the seiche that buried the fish. These leaves showed damage from "leaf mining"—a type of insect damage that occurs when insect larvae burrow through leaves, creating meandering paths of destruction. Leaf miners are a bane to farmers and gardeners because they are inside the leaf, not on it, making them difficult to control. But they are a boon to paleontologists, because their activity is highly seasonal, peaking just as the plants hit their own peak growing season. And, since leaf mining damage appeared to be "abundant" on 40% of the leaves entombed in the Tanis deposit, DePalma's team reported, that meant leaf-mining insects must have been highly active at the time the seiche ripped these leaves from their branches and buried them along with the fish. Exactly when in the growing season this occurred, he couldn't say, but definitely spring or summer, not fall or winter.

His second line of confirmation comes from the fossils of insects also trapped in the Tanis deposit, including those of mayflies.

Mayflies are gossamer insects akin to dragonflies (but much smaller) that can appear in enormous "hatches" in which they emerge, mate, and die, often in a matter of days. I myself once encountered such a hatch on a bicycle trip in central Wisconsin. It was a surreal experience, partly because the insects were drawn to the warm asphalt, above which they hovered like trails of smoke. At the time, I didn't know what they were and simply described them in my journal as "huge gnats, twice the size of mosquitos," so numerous that "breathing was difficult" and "I had to shield my eyes to keep them out from under my glasses. My hair quickly filled with trapped insects."

That's what a mayfly hatch is like, and from what DePalma and his team write, there appear to have been a lot of them around at the time Tanis River deposit was created: yet another indication that the Chicxulub impact occurred relatively early in the Northern Hemisphere growing season.

That doesn't mean it was in May, however. The term "mayfly" implies that the insects hatch in May, but DePalma notes that hatches can actually be any time between April and July. The one I encountered was on July 19.

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An Even More Silent "Silent Spring"?

A while back, I wrote a Guest Alternate View column about the amazing ability of scientists to peer far back in time to detect things most of us would have thought to be undetectable without a time machine.[5] This is yet another example of the stunning forensic tools modern science has at its disposal. But it's not just another "cool" discovery, because it has intriguing parallels to what ecologists learned in the aftermath of the 1980 eruption of Mt. St. Helens—something I wrote about in one of my first appearances in these pages, more than two decades ago.[6] It's not often that such disparate pieces of one's career get stitched together so nicely.

What Mt. St. Helens taught was that when it comes to the effects of a cataclysm, timing can be everything.

Mt. St. Helens blew up in May, when patches of mountain snow were still on the ground, protecting the underlying plants and possibly a few hibernating animals from incineration. That had a huge impact on how the mountain recovered, which was very different from what would have happened if the blast had occurred a month or two later, when all that snow would have been long gone. Of particular interest was the way in which the vagaries of snow patches and the eruption's timing created "refugia" from which survivors could emerge to recolonize a world laid waste. Prior to the Mt. St. Helens blast, this was an unknown concept to ecologists. Afterward, the revolution in thinking was so strong that much of ecologists' thinking about recovery from catastrophes can be divided into "pre-" and "post-" Mt. St. Helens understandings.

In the case of Chicxulub, there was no protective snow, at least not at sea level, at the time of the impact. If the new findings are correct, it was full-on spring in the Northern Hemisphere. Animals were just emerging from winter, waiting for eggs to hatch, or looking for food for themselves and offspring already hatched or born. But they weren't the only ones that were particularly vulnerable that time of year, because the blast blew massive amounts of dust and smoke into the air, blocking sunlight and causing temperatures to plummet into an extended "nuclear winter." That would have been a major problem for the plants at the base of the food chain. "We all know how [garden] plants can be extremely sensitive to sudden night frosts when just starting up," During says.

But that's the Northern Hemisphere. In the south, it would have been the reverse. Not only would many plants have already been preparing for winter, but many animals would also have been doing the same. Some might even have already been hibernating, or preparing to do so. Not only could that make them less vulnerable to immediate death, but it might have made them more prepared to emerge into the unexpectedly harsh post-Chicxulub world. Not that survival would have been easy in any case, which is probably why the impact took out all of the dinosaurs, north and south. "But anybody in the Southern Hemisphere already sheltering had a much better chance," During says.

There are, in fact, indications that this might well have been the case. Extinction rates in Australia and New Zealand appear to have been much lower than in the Northern Hemisphere. And there are indications, During says, that some surviving species, such as birds, survived in the Southern Hemisphere then slowly migrated northward to repopulate the Northern Hemisphere. Research by Daniel Field, an evolutionary biologist and paleontologist at the University of Bath, UK, has also suggested that all modern birds are descended from ancient ground-nesting species—not surprising if Chicxulub-induced wildfires destroyed all of the habitats of tree-dwellers.[7]

Field's findings not only reinforce the timing-is-important refugia hypothesis, but also emphasize how important this timing was for preventing the world from losing all of its bird life entirely. In 1962, Rachel Carson galvanized the modern environmental movement with her book *Silent Spring* about the threats of DDT and other pesticides to birds. But had the timing of Chicxulub been a bit different, it might have been a lot worse. "Only a small number of ancestral bird species, survived," Field wrote in *The Conversation*, "meaning that birds were lucky to make it through at all. We were almost robbed of the robins and finches in our gardens (and the seagull who made off with your hotdog) before they ever evolved."[8]

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The main implications of this for science fiction are obvious: asteroid impacts, dinosaurs, ecological catastrophes—all are staples of the field. The better we understand them, the better we can write stories about them.

But that's just a beginning. Much of science fiction involves looking at scientific and cultural trends and extrapolating to the future. Then comes plotting: trying to figure out how to weave them into a story. One of the best pieces of advice I've ever heard on that topic came from Lois McMaster Bujold, who described her process with the Miles Vorkosigan books as trying to figure out what was the worst thing that could possibly happen to poor Miles . . . then figuring out how to make it inevitable, based on his personality, that he would do it to himself.

That makes for great storytelling, and is part of why she's won seven Hugos and three Nebulas. But During's, DePalma's, and Field's research raises a different plotting issue: coincidences do occur, and they can be very important in the long-term arc of history (or a story). What would have happened if the Chicxulub impact had come three months later? What would happen if something similar hit us now in April, May, June, December, January, or February? How might that affect the reactions of political leaders in one hemisphere, as opposed to the other? Might one group, instead of seeing pending catastrophe, see a chance for advantage?

From a storytelling perspective, there are lots of ways to deal with that, including huge fights over how best to attempt to divert an incoming asteroid. If there's no time to divert it completely away from Earth, do you move it north? South? East? West? Depending on the time of year, the differences could be major, not just for your own part of the planet, but the future of the world as a whole.

If it's too late to save the entire planet, what part do you save? And who gets to make the choice? Because if there's one thing the new studies show, it's this: timing and location matter. Death and annihilation on the Tanis show us that the timing may well have saved us from 66 million years of silent spring.

Footnotes:

1 Melanie A. D. During, Jan Smit, Dennis F. A. E. Voeten, Camille Berruyer, Paul Tafforeau, Sophie Sanchez, Koen H. W. Stein, Suzan J. A. Verdegaal-Warmerdam & Jeroen H. J. L. van der Lubbe, The Mesozoic terminated in boreal spring, Nature volume 603, pages 91–94 (2022). https://www.nature.com/articles/s41586-022-04446-1.

2 Time Scales of Critical Events Around the Cretaceous-Paleogene Boundary. Paul R. Renne, Alan L. Deino, Frederik J. Hilgen, Klaudia F. Kuiper, Darren F. Mark, William S. Mitchell, IIILeah E. Morgan, Roland Mundiland, Jan Smit.

Science, 8 Feb 2013, Vol 339, Issue 6120, pp. 684-687, DOI: 10.1126/science.1230492.

3 Fonseca, M.d.C., Araujo, B.H.S., Dias, C.S.B. *et al.* High-resolution synchrotron-based X-ray microtomography as a tool to unveil the three-dimensional neuronal architecture of the brain. *Sci Rep* **8,** 12074 (2018). https://www.nature.com/articles/s41598-018-30501-x.

4 Seasonal calibration of the end cretaceous Chicxulub impact event. Robert A. DePalma, et al, Scientific Reports (2021) 11:23704. https://www.nature.com/articles/s41598-021-03232-9.

5 "Epistemology, Star Trek, and Iron Rain," March/April 2022.

[6] "Up in Smoke: How Mt. St. Helens Blasted Conventional Scientific Wisdom," April 2001.

[7] Daniel J. Field, Antoine Bercovici, Jacob S. Berv, Tyler R. Lyson, Vivi Vajda, Jacques A. Gauthier. Early Evolution of Modern Birds Structured by Global Forest Collapse at the End-Cretaceous Mass Extinction. Current Biology, 28(11), P1825-1831.E2, May 24, 2018, https://www.cell.com/current-biology/-fulltext/S0960-9822(18)30534-7?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%-2Fpii%2FS0960982218305347%3Fshowall%3Dtrue.

[8] "Daniel J. Field, "How birds survived the dinosaur-killing asteroid," The Conversation, May 24, 2018.

Richard A. Lovett has been in Analog *nearly 200 times in all departments ranging from fact to fiction. Eighteen of his best fact articles are collected in* Here Be There Dragons: Exploring the Fringes of Human Knowledge*, and his popular Floyd & Brittney stories are now a novel-length book,* Neptune's Treasure*, both on availble on Amazon.*