Mother Earth What A Life You've Had

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rev 2

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Chapter 1: What This Book is About

From the time I was told that an asteroid had brought about the extinction of the dinosaurs, I've been interested in "nasty things that happened to life on this planet."

I've read quite a few books and too many articles, but most of these focused on one event, or were proposing one theory or another, without giving much time to opposing theories. Some, on the other hand, were quite good.

So I felt the need for a brief summary of interesting and nasty things that people claim have happened to planet Earth and to its life; mostly about its life. This is a start; I wrote it for myself, and I'm sharing it in the hope of getting comments and further thoughts.

What This Book is Not About

It is not an attempt to be thorough or complete. It is not an attempt to promote one or another theory.

Cautions

This book does not go into detail and, sometimes, it's too short on references. If I were trying for a PhD thesis, I'd put some darn good referencing into it. But I'm just following an interest, and noting what I come up with. If I put a "fact" in here, it's because I got it from a book or from the Web, and for all I know it may be a fib or someone's silly guess, so be careful what you believe of the stuff here.

Some of the items are rather speculative. But I like that.

I don't understand some of the scenarios here and some of the explanations, but I include them anyway, in the hopes that they'll make sense to you.

It seems sometimes that every time I look up situation, there are a whole lot of other trails leading all over the place. Feel free to follow those that I didn't feel I had time for.

The links were valid when I wrote each section; that doesn't mean they're still valid. Sometimes I'll reference something in the text but you won't be able to find a link. You'll be mad, but remember, I'll probably do time in Hell for that.

My references tend to be casual. For example, if I say "Hypatia hit the Sahara desert in Egypt", I mean the area that is now Egypt". You knew that; so don't get all pedanticky on me.

I've cleverly hidden many typos in the book (see if you can find them).

On the other hand, this is a free book. And besides, I hope to update it often. If you want, you can send me your opinion, and tell me whether you want it in the book, with or without your name.

Terms and Notes

Glaciation: Lots of ice; some of it sliding around like it does on Greenland.

Gondwana: A former land mass made up mostly of today's continents, stuck together.

Temperatures are measured in Celsius.

Anoxia: No oxygen. When that happens to the oceans, the only surviving life is either burrowed into the mud at the bottom or living in fresh-water rivers running into the oceans.

Dates: There's a lot of play in the dates of some of these extinctions. Some are just hard to date, and some events seem to have come on slowly and left slowly, so setting an exact date is a matter of opinion.

Links

The first edition of this book included hyperlinks to web sites. That, it appears, caused some problems with displaying the text on some readers. I've removed the hyperlinks, but you can email me (see end of book) and I'll send you a .doc. .txt file with those links, or include them into the email.

The remaining links have been moved to the end of the book (instead of the end of the chapters). They're usually enough to allow you to find the article using a search engine.

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Chapter 2: Birth of the Moon

4.527 billion years ago

If you like following mysteries, there's no end yet to this one. Just when someone figures out a new and better theory about how the moon formed, 4.527 billion years ago, another person comes up with some new data to call the theory into question. If the earth wasn't basically a ball of molten rock before the moon formed, it probably was for a long time after.

If you wonder what the moon has to do with life on earth, well there's a couple of theories for that. One says that, without the moon, the earth wouldn't be so stable, flipping onto its side from time to time – and that can't be good for anybody.

Another says that the moon's gravity helps shift continents. The resulting volcanoes bring up radiation that helps prompt evolution.

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Chapter 3: Origin of Life

More Than Three Billion Years Ago

And here's another big mystery for you. Either planet Earth generated life, or got infested with life. I'm with the "infested with" camp, but that may be only because I was never very good at biochemistry.

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Chapter 4: Snowball Earth

700 Million Years Ago

The Theory

For a half-century or more there's been a theory that Earth, way back in its history, was frozen over. This wasn't like the last ice age, which lasted 2.6 million years and covered a lot of the northern hemisphere, No, this lasted 220 million years and covered most, maybe all, the planet.

A fellow was studying deposits from about 700 million years ago when he discovered what he thought were unmistakable signs of glaciation.

This wouldn't have been unusual – Earth has glaciers even now, near the poles, and on mountains – but he was sure the place he was looking at had been near the equator and underwater. "Just deposits from mountain glaciers," he was told by the skeptics. Mount Kilimanjaro, after all, has a lot of ice even today, and it's near the equator.

But, of course, he persisted, looking at whatever deposits he could find that were from the same era. Most were gone, having been run into the earth as the continents slid under each other, or having been eroded from highlands by weathering.

Eventually, he accumulated enough evidence to put out a scientific paper or two, then a book. He could not, he said, find any place on earth that hadn't been under glaciers at the time. "Snowball Earth," he called it, since a snowball is what the planet would have looked like from space. He figured the Earth had been covered with ice and snow entirely, although there might have been an open space or two near the equator.

There was, and is, a fair amount of skepticism. "Why would the earth have frozen over?" he was asked. "Why didn't all life die?" And, just as importantly, "What would have re-melted the earth?" A snowball earth would have reflected so much of the sunlight that it would never have thawed.

Nonetheless, he persisted in hammering away at outcrops and defying the critics who began hammering away at other outcrops.

This was, of course, before there were anything we'd call animals in the water, and not even plants on the land. Basically a planet with oceans full of pond scum.

The critics argued that such a long internment in an icy casket would have sterilized the planet of life. Supporters suggest that a few single-cell life forms could have adapted to life on the muddy bottom of the oceans.

Even while more people were finding more evidence of the ice cover, other people were coming up with interesting items. One group found ocean-floor features that could only have formed if there were major storms churning the water above – which implies that the ocean, at least at that location, was free of ice.

And a Scottish group found sedimentary material they assure us could only have come from floating ice – and that also implies an ocean open enough for ice to float on.

The answer to what stopped the ice and thawed the planet is, some have noted obvious; a round of volcanoes. These would blast through the ice and pump lots of carbon dioxide into the air, creating a massive greenhouse effect. There's a thought: volcanoes save the Earth.

There's an odd note here, too. After hundreds of millions of years of having only single-celled critters, the planet started producing more complicated animals not long after the snowball Earth schedule. Some suggest that extreme conditions produced new animals. Scientists from Woods Hole Oceanographic Institution in Massachusetts suggest that moving glaciers on land ground down rock, carrying phosphorus into the waters. The phosphorus produced the mother of all algae blooms. As the algae (and other small stuff) died, it settled to the bottom, taking the excess carbon with it. That left an atmosphere rich in oxygen, and evolution produced the first oxygen-breathing life forms.

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Chapter 5: The Cambrian Explosion of Life

541 Million Years Ago

The Cambrian is the first geological period of the Paleozoic Era, lasting from about 541 to 485 million years ago (mya).

"The Cambrian Explosion is widely regarded as one of the most relevant episodes in the history of life on Earth, when the vast majority of animal phyla first appear in the fossil record. However, the causes of its origin have been the subject of debate for decades, and the question of what was the trigger for the single cell microorganisms to assemble and organize into multicellular organisms has remained unanswered…." From Science Daily.

You dig into the layers of rock, and you find fossils of animals. That pretty well stops when you get to rocks older than the Cambrian, to a period called, of course, the Precambrian. For years people wondered why all these animals appeared. It was as if life suddenly exploded out of nowhere.

It took a long time before people figured out that what they were seeing in fossils was just the remains of shells, and that older types of creatures didn't particularly go in for shells. After a lot of diligent searching they started finding fossils of older life forms, but there's not many, so it does look as if life took off in a great blooming about 541 million years ago

One hypothesis is that there wasn't much oxygen in the world before the Cambrian, and very few predators (in today's world, any place that doesn't have much oxygen doesn't have many predators). Without predators, there wasn't much reason for shells.

Besides (the theory goes), since oxygen levels were rising in the Cambrian, animals, including predators, had a lot more energy to use becoming meat-eaters and hunting other animals for food. Pretty soon the predators developed jaws and the their prey developed shells and spikes and things that preserve nicely as fossils. It would have paid the prey animals to get bigger, leading to increasingly bigger predators.

Another hypothesis is that the Cambrian was when predators developed eyes, and got a lot more efficient at hunting things down. At that time it became important for other animals to develop shells (and, probably, eyes of their own).

Now, it is possible that the Cambrian wasn't just life getting more fossilizable because it got shells. Maybe there was a sudden explosion of life; life increasing in huge numbers. If so, they key would probably be the increase in oxygen.

But not right away. Near the beginning of the Cambrian there was a sudden decline in oxygen, and an extinction event. That was followed by a rebound in which oxygen levels came back then increased far beyond what they'd been.

The reason for the disappearance of oxygen (a condition called "anoxia". Remember that word; you'll need it a lot) is pretty well a complete mystery, but one theory for the rebound is the appearance of the mother of all plankton blooms. Given a bit of anoxia, you get a world with a lot of carbon dioxide in it. That raises the temperature, and you have a world with lots of warm oceans and lots of carbon dioxide to feed the floating plankton. (Plankton are floating water plants, mostly slimy and green.) That's a lot of happy plankton, and that's okay because plankton are the main life form on Earth.

According to one theory, the plankton growth went wild in the oceans. Plankton do an interesting thing; they absorb carbon dioxide (and use it to make more plankton) and give off oxygen. Conveniently, plankton die young, then drift down to the bottom of the ocean, carrying carbon (from the carbon dioxide they took) with them. They also breathe out oxygen while they're alive. This process removes carbon dioxide from the air and puts oxygen into the air.

And that, according to one theory, is how the Earth ended up with lots of oxygen in the Cambrian, leading to a lot of new life that used oxygen. (Myself, I note that carbon dioxide levels are rising today, and there are a lot of algae plankton blooms being reported, but those blooms don't seem to be removing carbon dioxide as fast as they should, but what do I know?)

Then there's the calcium theory. After all, not only were there a lot more multicellular animals (as opposed to single-cell things like amoebas), but many of them developed shells. Shells are made of calcium products (calcium carbonate, actually) and calcium, the theorists say, is essential for building a spongy framework for single cells to group together. They believe there were a lot of volcanoes along the mid-ocean ridges at the time, and those volcanoes pumped so much calcium that, well, things just started happening to life forms.

I'll have to look into this; I had no idea that volcanoes were big on calcium production, and I can't believe the preceding 500 million years (of single-cell life) didn't have as many volcanoes popping up from time to time.

I'd like scientists to come to a conclusion about one, maybe two, factors for the Cambrian explosion. It may be that there were a whole lot of things that had to happen about the same time, but that seems a bit wishy-washy for me. I'm a simple man.

There's a theory that those little floating and bottom-clinging calcifiers in the ocean have made all the difference in keeping the Earth's temperature within a reasonable range. If the air gets to have too much carbon dioxide, those little guys multiply, using the carbon dioxide to build shells, and, when they die, carrying that carbon dioxide (as calcium carbonate) to the bottom of the oceans. Or the clingy guys build coral reefs, likewise taking carbon dioxide out of the atmosphere. The sun is now about 30% more powerful than it was in those old days, but the temperature of the planet hasn't changed much. Thanks, guys.

On the other hand, if they did a perfect job, most of the rest of this little book wouldn't be nearly as long….

It would be unfair not to admit that many people insist that the beginning of the Ordovician resulted from a mass extinction of the previous Ediacaran life forms, pointing out that:

- There's a layer of black shale from that time, and that indicates an anoxia of the oceans.

- Almost no forms of life are found on both sides of the boundary. And the change seemed to have happened too slowly to have been a gradual evolutionary replacement; it's more like new forms invading a cleaned-out environment.

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Chapter 6: A Breathable Atmosphere

500 Million Years Ago

This seems to be more or less the same as the one before, the Cambrian explosion. It's 40 million years later, but I guess there's some slop in the dating when you go back that far.

Anyway, an Ohio State University researcher was working on the question of how oxygen vanished from the Earth's atmosphere during the Cambrian, then returned at higher levels than ever before. Which is to say, life, extinctions, even more life, as a sequence.

The researchers believe the oceans (which had the only known life on the planet) became anoxic, which means they ran out of oxygen. That, if nothing else, would be hard on the trilobites on the bottom. Small bodies of fresh water in the cold latitudes still do that today, in winter, under the ice; most animal life dies. Nobody knows how the oceans ran out of oxygen in the first place, but 500 million years ago the oxygen came back. The guess is that plankton – which are plants and so like a lot of carbon dioxide around in the water – grew like crazy. As they died, they sank to the bottom of the ocean, each taking a bit of carbon dioxide with it. When enough carbon dioxide was gone, the animals – new animals – came back to the oceans. Most of the types of animals we know (including vertebrates) appeared.

A couple of researches from the University of Durham think there was a dramatic rise in the sea level at the time. This resulted in lots of shallow seas, bathed in sunlight and full of chemicals leached from rocks. These chemicals included calcium, which would have been poisonous if the animals hadn't figured out how to use it to make shells. Once shells were evolved, the predators rushed to evolve jaws and claws. Once predators with jaws and they prey with shells got locked into an arms race, well, evolution produced animals that fossilized nicely for us. Which gives us the appearance of an "explosion of life, when it's as much an explosion of fossils.

Just as handily, some animals learned to escape the new predators by burrowing into the seafloor. Their holes and tunnels allowed oxygen-rich water into the mud, creating a new habitat.

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Chapter 7: End of the Ordovician

455 Million Years Ago

The Ordovician period lasted around 42 million years. I grew up along the Trent Canal in Ontario and spend a lot of summer days walking on the chunks of rock they'd dug up to make the canal. The rocks were a few centimeters thick, a dirty gray color, and just full of fossils from the bottom of the shallow Ordovician seas.

I never found a complete trilobite, although that's the most famous fossil type from the period. It is believed that there were no important life forms on land during most of the period, but it was, to judge by the sheer number of fossils, a good time in the waters. Carbon dioxide levels were between 14 and 22 times as high as now, and the earth was about five degrees Celsius warmer than now. It would have been hotter, but the sun was putting out less light.

It all came to an end somewhere around 455 million years ago. Within ten million years there were two major episodes of glaciation. Most of the continents were stuck together at the time in a supercontinent called Gondwana (although the future North America was near the equator), and that land was at the south pole, so ice had an easy way to form.

And about 75% of marine species went extinct, including the trilobites. Okay, extinct trilobites aren't as interesting as extinct T-rexes, but they'd been around a long, long, time, and suddenly they were gone, in what was the second-greatest extinction event in Earth's history.

The question is, "why"?

The Land-Plants Theory

Well, with all that carbon dioxide in the air, the planet was not going to freeze, so one theory is that the carbon dioxide levels dropped. Since there's nothing as effective as plants for getting carbon dioxide out of the atmosphere, one theory says there was a dramatic increase in plant growth.

Bare rock, it is known, does take some carbon dioxide out of the air, but there had been bare rock before and besides, things seemed to have changed too quickly for rock to have been to blame.

The scientists behind this theory say, instead, that plants learned how to live on land. Little plants that looked a lot like moss. They spread across Gondwana, sucking up carbon dioxide to make more plants. Less carbon dioxide in the air meant the temperature of the planet dropped, glaciers formed on Gondwana and anything that couldn't adapt perished. That would include the plants on Gondwana, so they were the creators of their own doom.

Then, about the time the system started to warm up from the first glaciation, bang, we're into another one. The same scientists think that plants had evolved into "vascular plants". Vascular plants have little tubes for moving nutrients around. This makes them more efficient, and they can grow larger. Growth takes off again, the new plants suck more carbon dioxide out of the atmosphere, and we're into the second glaciation.

Now most life was still in the oceans at the time, but the bulk of that life was living on the bottom of warm, shallow seas. The oceans not only got colder, but glaciers on the land used up water, and the ocean levels dropped, leaving fewer shallow areas and more deep areas that light couldn't penetrate. That's the theory, anyway.

Further Research into the Climate-Change Theory

Researchers at the California Institute of Technology (Caltech) also looked into the idea that climate change was tied to the late-Ordovician extinction. It seemed just too much of a coincidence that the extinction happened at the same time as the glaciation. They reckon that the temperature of tropical surface waters dropped as much as five degrees and there were more glaciers on the planet than during our more recent ice ages.

Personally, I'm just a poet, but my suspicion is that while climate change can reduce the quantity of life, an extinction event seems less likely. I figure that life adjust, with cold-tolerant creatures finding new opportunities and new shallow seas forming where there was deep water before. After all, the tropical waters at the time may have cooled five degrees, but they were still warmer than today's tropical waters.

Unless, of course, the change is very rapid, but then you're into asking why such a rapid change happened, and that raises the suspicion of volcanoes or asteroid/comet impacts as a cause.

The climate-change theory was further developed by scientists at Caltech and the University of Wisconsin, who concluded that the shallow seas were the habitat of most life and the areas most affected by the glaciation on the land (because of the lowering of sea levels).

The Invasive Species Aspect

A study from Ohio University looked more closely at the early North American continent, named Laurentia, which had a tropical climate and was near the Earth's equator. About this time the first of the Appalachian Mountains were poking up and shallow oceans forming behind them. Separated into different areas, organisms become different species. If they meet again, one is likely to be more aggressive and successful. This can, for a time result on less species diversity as the aggressive variety wipes out the other varieties. This would give fewer species (thus the impression of an extinction event) but not necessarily fewer individuals overall. Maybe there was less of an extinction than people thought.

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Chapter 8: The Lau Event

420 Million Years Ago

A report from the GeoBiosphere Science Centre of Sweden claims that there was an extinction event 420 million years ago. Things seem to have recovered fairly quickly, though.

Those of us who hadn't heard of this extinction probably hadn't heard of the Ludfordian faunal stage, which it preceded, either.

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Chapter 9: Late Devonian mass extinction

375 Million Years Ago

A UN-sponsored research team (you didn't know there was such a thing, did you?) found evidence of a mass extinction 375 million years ago. At the time, life may have been still all in the water, as far as we know, so problems with the marine ecosystem was problems with life. Somebody probably saw an unusual-looking line in the levels of rock somewhere and said, "Hey, what's that?"

Anyway, the group decide that this extinction was caused by plants. The world was warm and the atmosphere was rich in carbon dioxide, as high as 4000 parts per million. There were no ice caps.

That's when plants learned to adapt themselves to the land. Bingo; the plants spread across the once-barren landscape, years ahead of any animals that could control them. Those plants used up so much carbon dioxide (to make more plants) that they reduced the level of carbon dioxide right down to 400 parts per million. That's higher than we have now, but it was such a dramatic change, including climate cooling, and living things that couldn't adapt died. One more extinction event for the planet.

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Chapter 10: Hangenberg extinction

359 Million Years Ago

Myself, I can't recall ever catching a fish that wasn't of the ray-finned type, which says a lot about either my fishing abilities of the sheer number of types of fish that are ray-finned. In fact, other than lampreys or sharks, a person isn't likely to meet any other type.

There were lots of other kinds (mostly lobe-finned fish and armored fish) before something called the Hangenberg Extinction, but a real shortage of all fish for a while after. Eleven million years later, a small fish with a mouth adapted to crushing shells shows up in the fossil record. (At least scientists suspect the very large tooth plates on its jaws must have been used for that purpose.) Sea urchins, sea lilies, and invertebrates with shells survived the extinction, and would have made good food for the first ray-fins. Actually, for a while, these tough customers must have been the only food available.

This one seems to be the ancestor of most of the fish we know, from eels to salmon, from puffer fish to tuna. The original ancestor is long gone (although its close relatives lasted a hundred million years, which isn't bad), but nowadays, it's descendants are the most successful type of vertebrate animal on the planet, the ray-finned fish and include at least 30,000 species.

We have to remember that at the time of the Hangenberg extinction, there weren't any animals on land, according to some theories.

The time before the extinction is called the Age of Fish, because if was dominated by the large armored and lobed fish. With the Hangenberg extinction, that age was over. The planet warmed and the seas rose for a while, then the planet cooled again, with a lot of glaciers around.

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Chapter 11: Carboniferous Rainforest Collapse

305 million years ago,

You were wondering where all that coal came from? Picture ferns, jungle, amphibians, reptiles, and giant dragonflies during the carboniferous and vegetation rotting in peat piles.

Then the world turned hotter and drier, as carbon dioxide levels dropped. That was good for reptiles, but not so good for plants.

For suspects, we have a crater, called the Woodleigh Crater, in Australia, from about this time. and a major eruption about 296 million years ago.

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Chapter 12: Permian-Triassic Extinction

252.2 Million Years Ago

The Permian was a period when all the continents were together as one big continent. The swamps and rainforests of the previous Carboniferous were mostly gone, leaving dry lands and deserts on most of the land, with the first modern trees (such as conifers) showing up. This, it turns out, was especially good for reptiles.

The seas were still full of trilobites and the woods full of insects. Large lizard-looking things that would evolve into mammals and dinosaurs clomped across the landscape, eating each other.

Then came the extinction. It's sometimes called, "The Great Dying."

The extinction that divides the Permian period from the Triassic period (first of the dinosaur times) is currently regarded as the biggest extinction event in Earth's history, so it's been the subject of an unusual amount of study – and debate. 90% of ocean species disappeared, and 70% of land animal species, including quite a number of insect species.

Note that this 70% of land species, means species, not individuals. If 99.9% of a species of amphibian is killed off, but the 0.1% survives to reproduce the species, that species isn't listed as one that was killed off in the extinction. It has to be 100% of all individuals in that species.

Researchers from China and North America, examining rock layers, calculate that the extinction lasted less than 200,000 years. They believe that the worst of it happened over 20,000 years, peaking 252.28 million years ago. If nothing else, this event led (eventually) to the age of reptiles.

Now we round up the suspects.

The Volcanoes

First thing you have to know about are the "Siberian Traps." At the time of the extinction, volcanoes up in what is now Siberia poured out an amount of lava that covered an area the size of Greenland. That's the largest episode of volcanism known. It could be just a coincidence, but those volcanoes are the main suspect. There was another area of volcanoes erupting in China, but it was smaller, and might be named as another part of the problem.

Note that if volcanoes are the culprit, it wouldn't have been a sudden thing. Researchers at USC think the volcanoes could have started as much as twenty million years before the normal "extinction" date given, with the effect adding up over time. Chipping away at rock layers has convinced them that the organisms in the deep waters began dying first, with the ones in shallow waters disappearing last. They believe that the volcanoes released methane and carbon dioxide, creating global warming.

Global warming, in turn, heats up the oceans, which can then hold less oxygen. The deep areas become free of oxygen and organisms that can't tolerate oxygen (anaerobic bacteria) grow there. These produce large amounts of hydrogen sulfide (sewer gas), which poisons life. Just as nastily, hydrogen sulfide damages the ozone layer, and damaging ultraviolet rays fall on any animal or plant not shaded. (It's possible that the same sequence was responsible for the extinction at the end of the Triassic, 200 Million Years Ago.) This may have been accompanied by a slowdown in the circulation of the oceans. Today, the oceans have massive currents that circle the globe, delivering oxygen to all parts of the ocean. If this circulation stops, it's more likely that dead areas will occur.

Not that there aren't skeptics around, of course. Researchers at University College Dublin measured the charcoal from the extinction time period and claim that there's enough charcoal to indicate wildfires, but wildfires were less likely to happen if the Earth was low in oxygen (less than 12% in the atmosphere) at the time.

Space Rocks

Yes, there are people who don't put the blame, or at least all of the blame, on volcanoes. A researcher from The University of Western Australia acknowledges that the Siberian Volcanoes weren't doing higher life forms any good, but the disappearance of so many seemed to be a bit to abrupt for just volcanoes. He suspects a space rock, an asteroid or a comet, bid the final bit of dirty work.

There were some pieces of meteorites of the right age in Antarctica, but it took a while to locate a crater. Then they found one, the Araguainha crater, in Brazil, from approximately the right time. Critics say it's too small a crater, but proponents say it hit right in some oil shale. The impact, with associated earthquakes, could have resulted in fracking gone wild, releasing massive amounts of methane into the atmosphere – and starting a global warming event.

And if you still think the Araguainha crater was too small, researchers from Ohio State University and NASA think they've located a really big crater, formed about the right time, beneath the ice in Antarctica. This sucker might even have been big enough to shatter the foundations of the supercontinent, eventually setting Australia adrift. It's a bit speculative, since only drilling would tell for sure and they'll probably never get that much research money.

Magnetic Blip

Researchers at the University of Tokyo suggest that a plume of super hot material began rising from the edge of Earth's molten core 15 million years earlier. This screwed up the planet's magnetic field. That, in turn, allowed more radiation from space.

The radiation from space broke the atmospheric nitrogen into ions; these acted as seeds for clouds. The overcast cooled the earth. Then, as few million years later the hot material reached the surface as many, many volcanoes, which didn't help matters much.

Accessories After the Fact

Even if we accept the theory that Siberian volcanoes were the main cause of this extinction, there's a question of how volcanic eruptions kill off so much life. Following are a few theories that apply at least, to this one.

Coal Ash

Some Canadian geologists have found coal char in deposits at that era. They suspect that the culprit wasn't just the Siberian volcanoes, but the unfortunate coincidence of the lava from those volcanoes igniting huge coal deposits that happened to be in the same area. That produced coal ash, which is toxic to marine animals.

The Microbes

A fellow from the Massachusetts Institute of Technology blames microbes. He thinks the volcanoes themselves couldn't put enough carbon dioxide into the air to kill off so many species. His opinion: Methanosarcin – a methane maker that's still around and is responsible for most of Earth's natural methane. Analyzing the genome of this microbe, the calculated that it learned to make methane about 230 million years ago. That's close. Coincidence? He thinks not.

Methanosarcin needs lots of nickel if it's going to produce lots of methane. This fellow tested the deposits from the Permian-Triassic extinction and found peaks of nickel at that time. He believes the volcanoes were putting out unusually high amounts of nickel. That produced unusually high numbers of Methanosarcin, which produced unusually high amounts of methane, triggering acid oceans and runaway global warming.

Mercury

This theory comes from a guy at the Natural Resources Canada. Volcanoes put out a lot of mercury, and the Siberian volcanoes must have emitted a truly large amount. Mercury's poisonous to living things, but algae in the ocean absorb it, and carry it to the bottom when they die. The idea is that there was just too much Mercury for the algae at the time to absorb, so the rest of the life forms got exposed to it.

Worse yet, mercury in the ocean is converted in coal-burning to monomethylmercury, which is especially prone to accumulate in living things. And, of course, there's the evidence of those huge coal deposits that were ignited by the volcanoes.

Temperature

Temperatures rapidly rose by up to ten degrees Celsius, according to one source. Then again, researchers at the University of Leeds and China University of Geosciences, together with the University of Erlangen-Nurnburg, figure that there was a temperature rise in the tropics of around 50-60°C on land and 40°C at the sea-surface. I mean, that'll kill darn near anything. Heck, that would cook things. With the plants dead, there's not much to absorb any carbon dioxide in the air. Only at the poles would any significant life survive. We're a long way from Snowball Earth at that time.

And the Recovery?

How does a planet recover from a disaster like that? Well, here are some notes about just that subject.

Algae Run Wild

Stanford researchers believe that the oceans were pretty low in oxygen for five million years after the extinction (earlier timetables gave 30 million years), and that certainly slowed down the repopulation of the waters. As I said, the deep areas become free of oxygen and organisms that can't tolerate oxygen (anaerobic bacteria) grow there. These produce large amounts of hydrogen sulfide (sewer gas), which poisons life. Just as nastily, hydrogen sulfide damages the ozone layer, and damaging ultraviolet rays fall on any animal or plant not shaded.

The carbon dioxide produced by the volcanoes also produces acid rain. As if the acid rain weren't enough of a problem to the oceans, acid rain also washes minerals off the land above the water; these act as nutrients to produce even more algae, that uses up even more oxygen. It gets like the waters at the end of the Mississippi, only on a global scale. The Green Ocean effect, they call it.

But researchers at the University of Calgary and the University of Alberta believe that the shorelines of ancient Alberta, British Columbia, and the arctic acted as a one of the refuges for organisms. For some reason, these areas – perhaps with an influx of fresh waters – kept enough of the oxygen-needing lifeforms alive long enough to eventually repopulate the oceans. Perhaps the land didn't suffer as badly as the oceans during the extinctions; it's hard to tell, since most fossils come from ocean deposits.

Even On Land

Researchers from University of Utah, the Utah Museum of Natural History in Salt Lake City, and Whiteside of Brown University agree that the Permian-Triassic Extinction wasn't a single-time event. Rather, they think that during the recovery there were "echoes" for five or six or years after, as the planet reached for stability again. No sooner would species learn to adapt the one situation, than the atmosphere would abruptly change again, as different factors came into play, oxygen and carbon dioxide going up and down like a seesaw and leading to boom-bust environments. Some of this might have been from more volcanoes, and other episodes from a battle for dominance among oxygen-loving and oxygen-hating microorganisms in the oceans.

Note:

The Permian-Triassic Extinction is, at this point in time (2013-12-24), considered the mother of all extinctions. It is very heavily studied in hopes that it'll be able to explain how some of the other extinctions worked. I've only skimmed the surface of theories and arguments available, but that's all I intended to do. You can open any one of the links here and find other links. Me, I'm going on to the next extinction.

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Chapter 13: The Triassic-Jurassic Extinction

200 Million Years Ago

The period after the Great Dying saw the rise of animals (like pseudosuchians) that were ancestors of both mammals and reptiles. About midway through the period dinosaurs evolved, but didn't appear to dominate the planet like they would later.

Then, about 200 million years ago, half to two-thirds of the species on the planet died off over a time scale of up to 100,000 years, species in the seas and on land. First suspect is a series of volcanic eruptions that happened about this time, pumping our a million cubic kilometers of lava. (The continents were breaking apart and, well, cracks formed.) This raised the atmosphere's temperature about three degrees, with the resulting global warming. For tens of thousands of years, there would be alternate warming (from the carbon dioxide) and cooling (every time the volcanoes pumped enough sulfur into the air).

The dinosaurs survived this event and went on to dominate the planet for the next 135 million years. Credit for this has been given to both the disappearance of the crocodile-like pseudosuchians and to a superior breathing system that let dinosaurs live happily when the oxygen levels dropped.

Researchers from Columbia University's Lamont –Doherty Earth Observatory weren't content with the volcano theory and went looking for a space-rock impact, along with fern spores, and iridium traces. Some kinds of iridium are associated with space rocks, and some kinds of ferns are the first thing that grows back onto a devastated landscape. They found a crater about the right size and age in France, but are, at last report, still studying the drill cores.

At the same time researchers at MIT, Columbia University and elsewhere have managed to pinpoint the volcanic activity to exactly the same time (within 30,000 years) as the extinctions began, making them sure that the volcanoes, at least this time, did the deed.

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Chapter 14: Ocean Acidification

120 Million Years Ago

120 million years ago puts us into the Cretaceous, the last of the three great Dinosaur periods (the one with lots of T-rexes and triceratops).

At that time the ocean chemistry changed (though not as fast as it's changing now) and became much more acidic. This normally happens when there's an excess of carbon dioxide in the air. The carbon dioxide is absorbed into the water, where it forms a weak acid. That causes problems with ocean life that isn't adapted to the acidic water, especially with animals that have shells – the shells dissolve in acids. Coral reefs, which are made of old shells and similar compounds, disappear.

(Some creatures, surprisingly, manage to change the chemical composition of their shells or just grow really thick shells and survive.)

The surface waters became acidic first, then the deeper waters. After 160,000 years, the oceans had returned to normal.

How did this happen? We, of course, round up the usual suspects, the volcanoes. A series of big eruptions (I'm not sure just where, but it doesn't seem to matter) chucked carbon dioxide into the air.

Anyway, given enough time things go back to what passes for normal. I bet that humanity, by pouring powdered limestone into the water, could neutralize the acids much faster than 160,000 years, as long as the machinery and effort to do that didn't produce as much carbon dioxide as it neutralized. Fusion power, where are you?

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Chapter 15: Undersea Volcanoes

94 Million Years Ago

This one happened during the later parts of the dinosaur eras. It doesn't appear to have been studied much. It came to note when they found a thick layer of organic matter from the ocean floor of that time. In other words, a lot – and awful lot – of things died, and fairly quickly. Some ocean life forms became extinct (I'd like to know which ones).

Scientists figure this wasn't an asteroid impact; they found higher levels of osmium, and that tends to come from volcanoes, not space rocks. The seas were warmer then, without as many currents as we have today, so the thinking is that something had taken the oxygen, to make so much life die off.

Perhaps undersea volcanoes released a large load of nutrients. An explosion of life used up the oxygen, dying and sinking to the bottom. That was handy, since all that dead life produced some of our oil deposits. The removal (to the ocean bottom) would have cooled the planet, but not to worry; the whole thing was back to normal in ten to fifty thousand years.

Or maybe a bit longer. Scientists from Oxford University believe a warmer earth atmosphere weathers rocks faster, taking carbon into the oceans, where organisms eventually lock it into the bottom mud. Then the planet cools again.

29 million years later came the extinction of the dinosaurs.

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Chapter 16: Ocean Anoxic Event

93 Million Years Ago

Anoxia is when the ocean ran out of oxygen. This, you are probably aware, happened before.

In fact this and the previous "Undersea Volcanoes" may be the same event, if it took place over a long time or if scientists didn't bother to date things too carefully.

Anyway, 27 million years before the dinosaurs went extinct, at a time when T-rexes were still wandering the land, the world seems to have gone into a brief period of global warming, and the oceans seem to have run pretty low on oxygen.

Scientists from Oxford (studying rocks in England probably because they couldn't get grants to go further) figure 10,000 years of volcanic eruptions caused the greenhouse warming and the oceanic acid. Then, they figure, rivers carried enough minerals (especially, I imagine, limestone), to neutralize the acid and return the oceans to (more or less) health in 300,000 years. More carbon dioxide means more acid rain. The acid rain washes the minerals into the waters. The plankton grows like crazy, uses up carbon dioxide, and carries the carbon dioxide down to the ocean bottom. Things normalize. Only 300,000 years, you say.

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Chapter 17: Cretaceous-Tertiary: The Dinosaur Extinction

66 Million Years Ago

The Common Theory

This is the big one, in most people's minds. That's because we miss dinosaurs; they were really cool!

Possibly the most interesting thing about this extinction is that the cause is still up for debate. Yes, I know, we're almost all convinced an asteroid did it. Some of us know about the long fight between the evil-volcano theory and the evil-asteroid theory. And there was definitely an asteroid (or perhaps a comet) smacking into the Earth about the time the dinosaurs – and about half the species on Earth – vanished.

Exactly how an asteroid kills off things not directly under it is a matter of speculation, but some theories include blocking the sunlight till the vegetation died, wiping out the ozone layer, global cooling, global warming, or acidifying the oceans. There are plenty of good ways.

Stay tuned (if you care) – the jury's still out, whether you think so or not.

For one thing there was also a truly massive bunch of lava from volcanoes near India (called "The Deccan Traps") about the same time, and some of the volcanoes-did-it people claim that the asteroid hit was just a bit before the extinction, and didn't actually cause much damage. An examination of the ocean-bottom mud doesn't show all that much of a problem – and the bottom creatures depend on falling bodies from above. If 93% of the plankton near the surface died (as is believed) why were creatures near the bottom of the southern oceans not affected as much? Was it because the rock hit in the northern hemisphere? Anyway, the plankton took 270,000 years to recover, and since that plankton is the basis of the ocean food chain, all the oceans should have been pretty dead by then. It's been suggested that the 270,000 years is an amazingly long time for plankton to come back, and maybe metals from the asteroid (metals such as copper, lead, and mercury) took that long to settle out of the water.

Digging down through layers of rock on land, you get to older and older layers. Eventually you get to a dark layer about 65 million years ago. Below (older than) the layer = lots of dinosaurs. Above (younger than) the layer = no dinosaurs. Scientists call the era before the boundary the Cretaceous (and use the letter K for it) and they call the era above (younger than) the Tertiary. (Most people just call the Cretaceous-Tertiary boundary the K-T boundary, but I have more ambition than that.)

So what killed the dinosaurs, on or about the time that rock at the Cretaceous-Tertiary boundary was laid down?

Evidence for an Asteroid Impact

There is, of course the matter of the crater, 180 km in diameter, on the Mexican coast. After that was found, there was no doubt that a big chunk of rock hit the Earth, and that wasn't going to be good for the planet.

But some scientists think that the rock hit Earth about 300,000 years before the end of the Cretaceous. They say, "Look. Rock hit, then some layers of sediment, then the end of the dinosaurs. 300,000 years of sediment."

The critics say, "Sure, there's lots of sediment after the impact. What do you expect with tsunamis and earthquakes all over the planet?"

The people who believe the rock wasn't the end of it say that those sediments look like they took a long time to get there. They even have burrow-holes from happy little critters in them. They say, "Hey, we counted 52 species of animals in the soil before the impact and the same 52 in the soil after the impact. So the impact was no big deal."

And they point out that Earth had four previous extinctions, and there's no clear evidence that any of those four was caused by anything other than volcanoes. Volcanoes can kill oceans, if they warm the waters enough. The oceans at the time contained lots of hydrogen sulfide that could have been expelled from the oceans and drifted over the land, killing off animals.

Nonetheless, a couple of years later an asteroid was found "guilty" by a panel of 41 "international experts" who reviewed 20 years of studies. The main argument is that the volcanoes that laid down so much lava (called the "Deccan Traps" off India had been going on for half a million years before the dinosaurs vanished, without showing much effect. The panel also agreed that the sediments after the impact were as a result of the impact, and weren't 300,000 years old at all. That fact, the panel says, that chunks of impact quartz were found all over Earth shows just how severe the impact was. Case closed.

One item of note is that the media usually refers to an "asteroid" as the thing that hit the earth. Some scientists even think they've pinpointed a collision between a couple of asteroids, and that collision chucked one like a billiard ball at the Earth.

Or a Comet

But other scientists ask, "Why not look at a comet?" A comet is made up of rock and either ice or snow. Comets may not be as solid or even as large as an asteroid, but it's been coming in toward the sun from a long ways out there, and has built up a nasty bit of speed. And there's billions of them out where that one came from. On top of that, the scientists claim that the chemical make-up of a comet more closely matches the chemicals found at the Cretaceous-Tertiary boundary.

The amount of iridium and osmonium, they conclude, was too little for an asteroid. But about right for a smaller body. But for a smaller body to have made a 180 km-wide crater, it would have had to be travelling pretty fast. Faster than an asteroid, which comes from an orbit in the same direction as Earth, and not all that far away. Which might indicate a comet; comets come from very far away and have a lot of time to pick up speed as they head toward the sun.

There is a bit of a mystery as to why some species survived and others – including all dinosaurs (if you don't count birds) – vanished. Generally, it was the larger animals that didn't make it and dinosaurs, well… they were big. Myself, I find it difficult to believe that some island, somewhere, didn't have little dinosaurs that should have survived.

Or Volcanoes

As we said, there was also a truly massive bunch of lava from volcanoes near India (called "The Deccan Traps") about the same time, and some of the volcanoes-did-it people claim that the asteroid hit was just a bit before the extinction, and didn't actually cause much damage.

One big problem with the asteroid theory for the Cretaceous-Tertiary extinction is that scientists will tell you there have been five "major" extinctions on earth (with the Permian-Triassic being usually counted as the biggest). And those same scientists are pretty sure that the other four were all caused by volcanic eruptions. They've found evidence of large amounts of lava being laid down at the same time as each of those events.

So when they find that, about time of the Cretaceous-Tertiary extinction, mother Earth was blowing off almost inconceivable amounts of lava near India, well, you can understand their suspicions.

The people who favor the volcano theory now say that the years of volcanic action had reduced the number of dinosaurs to almost nothing. Then came the asteroid and finished off the few that were left.

Or…

Then there are a bunch of other theories. In a book called My Beloved Brontosaurus, a fellow named Brian Switek lists many of the theories that have appeared over the years, including the caterpillar theory. In this, the plant-eating dinosaurs depended on lots and lots of vegetation. When the moths and butterflies evolved, their caterpillars so reduced the number of leaves on the planet that the dinosaurs starved. Eventually, caterpillars developed their own enemies, but by that time it was too late for the big reptiles.

The Latest Evidence (2013)

Researchers used argon-isotope dating methods to pin down the Chicxulub crater (the big one) to get a more exact date of 66,043,000 years ago for a mass extinction. That, they say, is within 32,000 years of the impact, give or take a bit. That tends to rule out the competing theory that the dinosaurs were gone 300,000 years before the impact.

Other researchers concluded that the impact triggered worldwide fires that killed off life. They have found, they feel, more than enough carbon in the rock to justify that conclusion.

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Chapter 18: Paleocene–Eocene Thermal Maximum (PETM)

55.9 Million Years Ago

The PETM happened about ten million years after the dinosaurs vanished, and fifty million years before the first vaguely human apes started on their trip to the handsome beings we've become.

It's considered very important because a runaway, human-made greenhouse event could (if some people are correct) duplicate the effect. That is, if warming gets into a positive-feedback loop where methane from the permafrost bubbles out to add to the carbon dioxide we produce, well, the planet's environment could look a lot like the Paleocene–Eocene thermal maximum. So let's have a look at this one.

The common consensus is that the Paleocene–Eocene thermal maximum was triggered by a surge of carbon dioxide into the atmosphere. It was about as much carbon dioxide as we're putting up there right now, but the most common belief is that some volcanoes were the culprit then. Temperatures went up 5 degrees. The heat subsided, but then was followed by two smaller but similar heat waves. All in all, the temperature stayed up for most of 170,000 years before returning to more "normal" levels.

Sea temperatures went up about five degrees Celsius, and the sea levels, which had been rising before the event, rose even higher as ice melted all over the planet, reaching a peak about 13,000 years into the Paleocene–Eocene thermal maximum. The oceans were acidified (deadly to shell-making creatures) and took 125,000 years to get back to normal, and ten million years before shelled creatures re-evolved.

Two things happened of course. Life-forms that couldn't take the heat either died off or migrated north where it was cooler.

Another coincidence is that the Paleocene–Eocene thermal maximum happened at (or about) the same time as the moving continents created land bridges. At that time, mammals moved into the Americas.

A study at the University of Massachusetts may have pointed at the methane hydrate (also called methane clathrate) is found along the bottom of the oceans, and at high (cold) latitudes. Methane is trapped inside a crystal structure of water. Heating that water breaks the crystals, and methane bursts out.

It's a matter of getting the oceans warm enough for the methane hydrate to start releasing methane. That, in turn, increases global warming dramatically. At the time of the Paleocene–Eocene thermal maximum, the orbit and tilt of the earth led to a general warming. If that triggered a release of the methane, runaway global warming would result.

Scientists really don't understand what happened in the Paleocene–Eocene thermal maximum, and so are concerned that they may not understand what could happen with current global warming. Some scientists believe that the concentration of carbon dioxide in the Paleocene–Eocene thermal maximum rose by only 70%. Yet the earth warmed dramatically. So far, we've managed to raise the concentration by 30%.

Right now, it looks like the current rate at which we're pumping carbon dioxide into the atmosphere is greater than the rate at which the Paleocene–Eocene thermal maximum happened, which is a bit ominous.

One possibility for the cause is a runaway greenhouse gas event. In this:

1. Volcanoes belch out lots of crap.

2. Unfortunately for all concerned, they also start fires in some extensive coal fields (and maybe thaw some permafrost thereby increasing methane burps up north)

3. When the oceans get warm enough, the methane hydrate (also known as gas hydrates or clathrates) break down, and even more methane is released into the atmosphere, warming the planet even more. The methane oxidizes into carbon dioxide but that sure doesn't help the situation.

By that time (some people estimate) there was between 300 million and 1,700 million tons of carbon emissions going into the atmosphere each year. Heck, we're already doing lots more than that without volcanoes, permafrost thawing, or breaking down clathrates.

A different scenario blames the changes in the Earth's orbit. There are time when the shape of the orbit changes enough to warm the Arctic and Antarctic areas. So, in this scenario:

1. The Earth's orbit changes and it's no longer as cold near the poles.

2. Warming at these latitudes*thaws some permafrost thereby increasing methane burps up north)

3. When the oceans get warm enough, the methane hydrate (also known as gas hydrates or clathrates) break down, and even more methane is released into the atmosphere, warming the planet even more. The methane oxidizes into carbon dioxide but that sure doesn't help the situation.

4. After 10,000 years, the polar regions are pretty well out of methane, and the temperature stops rising.

5. After 200,000 years, the planet's back to where it was before the heating started. And the permafrost builds up again.

6. A million years later, the whole thing repeats, although with less permafrost around, and therefore a smaller thermal maximum. Eventually, the cycle just runs down and stops.

*If you're wondering about Antarctica, well, the planet was warmer than today even before the Paleocene–Eocene thermal maximum, and rather than icecaps, Antarctica may have had extensive permafrost beds.

Other theories include impacts from comets or asteroids, major forest fires, or the drying up of shallow ocean areas. The Earth-orbit theory, which puts the earth in a thaw-the-polar-regions-every-100,000 years, best explains the recurrence of heat waves, which seemed to happen about that often, at least for a while.

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Chapter 19: Middle Eocene

40 Million Years Ago or So. The MECO.

The Eocene period lasted from 55.8 to 33.9 million years ago. It was a nifty period. The dinosaurs were long gone, and humanity's ancestors were still swinging from trees. Very large mammals wandered around. In time-travel science-fiction books, people often choose to go back to the Eocene.

The whole planet was a lot warmer than today; there wasn't ice even at the poles, but by the middle Eocene it was starting to cool a bit.

Then the Middle Eocene Climatic Optimum happened. Things warmed up rapidly, probably due to a lot of carbon dioxide getting into the air. When it was first discovered, it was considered the most rapid global warming known. Suspicion for this warming falls on either the spreading of the ocean floor (lots of volcanoes) or something in the nasty way India bumped into Asia.

It didn't last long; a couple of million years, maximum. But it started with a doubling of the carbon dioxide levels in the air. Scientists at Utrecht University, working with colleagues at the NIOZ Royal Netherlands Institute for Sea Research and the University of Southampton figure all that was caused by India running into Asia, raising the Himalayas, since it happened at that time. More than that, they're not sure of. Volcanoes are usually the cause of carbon dioxide, but there don't seem to have been a lot of them as the Himalaya mountains got pushed up. Could be just a coincidence. Scientists admit they really don't know.

A Scientific American article says the warming lasted 400,000 years and was definitely caused by a doubling or tripling carbon dioxide. (Some people figure human-caused global warming might take that long to cure itself.)

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Chapter 20: Utah Supervolcanoes

30 Million Years Ago

I guess some supervolcanoes are hard to spot because they're so big. A supervolcano is a volcano capable of upchucking more than a thousand cubic kilometers of stuff. That's thousands of times more than your average volcano. There are a few of these around, including the one under Yellowstone. Scientists suspect these can create a small ice age, but that's just a guess.

The supervolcano near Wah Wah springs in Utah popped out 5,500 cubic kilometers, in a week, 30 million years ago, researchers from BYU estimate, leaving deposits up to 4 km deep.

Supervolcanoes are a common term for either of two types of volcano, massive explosive eruptions like Lake Toba, or large igneous provinces like the Siberian Traps. The Utah blast was an explosive eruption.

Compared to the Siberian Traps, the Utah eruption was pretty small stuff, and while we'd be missing the four or five states a similar eruption would bury (and undoubtedly the planet would have been without a summer for a few years), it wasn't a really that major an event, in terms of extinctions,

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Chapter 21: Sahara Comet

28.5 Million Years Ago

I've included this one because it's a bit different. According to South African researchers, a comet they call "Hypatia" hit the Sahara desert in Egypt about 28.5 Million Years Ago, leaving fused glass over 6000 square kilometers..

Other than that, there doesn't seem to be much information. Earth's undoubtedly been hit by a lot of comets, so I hope they study this one a bit more.

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Chapter 22: Pliocene Warming

5 Million Years Ago

Sometime in the Pliocene, when the Earth's temperatures were two or three degrees warmer than today and our ancestors were still probably trying to chip a rock into a spear point, the world's oceans rose as much as twenty meters.

A researcher at Imperial College London in the U.K. figures half that rise came from the melting of the East Antarctica ice sheet. At that time the West Antarctica ice sheet had melted and Greenland didn't have an ice sheet.

The sea level rise may have happened over thousands of years or much more quickly (they're still working on that part). Nobody seems to have come up with a cause for this warming.

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Chapter 23: The Ice Ages

One of the notable things about the ice ages is the fact that humans evolved from apelike ancestors during them. There's a common theory that this is no coincidence: as the world's climate seesawed back and forth, animal life had to adapt or migrate, or both.

Research by a British, Swiss and Spanish team has been studying cores drilled into marine sediments off the coast of South Africa. The cores cover the last 100,000 years, which is the time of the last ice age.

They found that when the north was covered with ice, South Africa was getting lots of rain. About that time, South Africa was probably one of the main hangouts for our ancestors; a good location to get protein from the sea while practicing chipping stones into spear points.

I know you're anxious to prove that meteors or volcanoes had something to do with the ice ages, so you'll be glad to know that a scientist from UNSW's Australia-Pacific Tsunami Research Centre and Natural Hazards Research Laboratory believes that a meteor the size of a small mountain hit the Pacific Ocean in one of its deepest parts, between Chile and Antarctica, 2.5 million years ago.

There wouldn't be much of a crater left, but the tsunami must have been interesting. More than that, the Earth was already cooling and the huge amount of all the water and soil blasted into the atmosphere could have accelerated a general cooling into a time of true ice ages.

Note: There are a lot of "glacial periods" in an "ice age."

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Chapter 24: East African Dryout

2 Million Years Ago

Two million years ago East Africa began to dry out. Grasslands replaced forest and herds of grazing animals spread out across the plains. Not a major change like some, but important to our ancestors, I guess.

People have been looking for the cause of this for a while and have suggested causes such as volcanoes (of course) and changes in carbon dioxide concentrations. But researchers from Columbia University believe it was caused by changes in the ocean temperatures. Areas of the Indian and Pacific oceans near the far east and Australia warmed while the areas near Africa and North America cooled. That changed the rainfall patterns over Africa.

But of course, someone has to find out why the oceans changed temperatures.

Researchers at Washington State University and the Scottish Universities Environmental Research Centre have pegged a couple eruptions from the Yellowstone supervolcano (I heard somebody mention volcanoes) about that time.

Personally, I can’t see how eruptions from a volcano can cause more than a few years of problems unless it changes the carbon dioxide level of the atmosphere. But I suppose they’ve checked into that.

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Chapter 25: Two Supervolcanoes

760,000 Years Ago

Around this time humans were shuffling around Africa, using spears and making fires.

A team from Southern Methodist University found evidence of a supervolcano in the Italian Alp’s Sesia Valley, in the form of a crater 13 km in diameter from an eruption 760,000 years ago.

People have long wondered what’s underneath a supervolcano (such as Yellowstone), and with the Sesia volcano they hit the jackpot. After the eruption, Italy continued its push into Europe, and nature boosted the whole volcanic assembly upward. Now scientists can climb up to look at the roots of a supervolcano. Handy.

About the same time there was another supervolcano, this time in Long Valley, in California.

Nobody has done much speculation on the effects of these two supervolcanoes, but we can expect a few climatic disruptions at least.

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Chapter 26: Antarctic Ice Sheet Collapse

200,000 Years Ago

Just what happens if the Antarctic ice sheet collapses? Will the oceans rise a lot?

Up till this point, you’ve been looking at events discovered by people looking at rock layers. This one, however, if based on genetic evidence from an octopus, an Antarctic octopus.

Antarctica was still at the south pole back then, so there was a warm period on Earth 200,000 years ago. More than that, we don’t know.

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Chapter 27: The Toba Volcano

74,000 Years Ago

In Sumatra, some 74,000 years ago, there was a rather large volcanic explosion. Not just an eruption; the blast left nothing but a hole (it's now Lake Toba), and chucked millions of tons of ash, sulphur, and miscellaneous other crap into the atmosphere. Scientists claimed it took at least a decade for the air to clear, and in that time, the temperature of the planet would have dropped about ten degrees Celsius. There would be snowstorms instead of summer for a lot of the planet.

For at least 20 years, those scientists pushed the idea that humankind, unprepared for such weather, almost perished entirely. We were, they concluded, down to a few thousand people.

It was an interesting idea. People were tempted by the concept that one volcano could do such damage and reduce the survivability of humankind to the roll dice. There's something philosophical about it, and it's built into our planet.

Other scientists, of course, jumped on the chance to challenge the idea.

Lately the challengers have been coming up with some good evidence that the cold snap wasn't as bad as first proposed (a drop of only a couple of degrees). They also suggest that the earth had been cooling before and humans had been adapting nicely to the cold before the volcano erupted.

An ice core drilled into the Greenland ice cap seemed to tell us that there was a sudden freeze, but it happened thousands of years after the Toba explosion. (Which, of course, leaves someone with the challenge of checking out what caused that cold snap….) Another group, from Oxford University, examined ancient sediments in Lake Malawi for traces of this climate catastrophe and couldn't find any.

Here's no doubt that the Toba explosion was huge, perhaps the biggest in humanity's history, and that the effects might be too sudden to escape by migration, but our species seemed to come through it, one way or another.

It's worth studying such events because, while we have what a major asteroid impact will do to the planet, we're less sure of smaller disasters, and more likely to experience them, if only from nuclear wars or a Yellowstone eruption.

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Chapter 28: The Ice Ages and the End of the Last Glacial Period

2.6 Million Years Ago to 10,000 Years Ago

Technically, we're still in the ice age that began 2.58 million years ago at the beginning of the Pleistocene epoch. At the moment, they say, we're just in a warm spell between glacial periods. There are a lot of glacial periods in an ice age; some people think there were 20 or 30 in this ice age. There may have been as many as four other times Earth went through an ice age, but, other than the "snowball Earth" episode, they haven't' got much study.

Now, I wouldn't have bothered with the ice ages in this book because I figure they didn't do an awful lot of harm to life on the planet. There were a lot of long-term migrations of course, and some life did better than others as climates around the world changed, but that's what you've got to expect if you're going to live on the outside of a planet.

During climate change, evolution speeds up as animals are forced to adapt, so that makes ice ages a bit more interesting.

And that's where the end of the last glacial period comes in.

The last glacial period started about 70,000 years ago, and ended about 10,000 years ago (dates are a little – well, a lot – fuzzy with ice age data, depending on where you take the measurements and how you define things).

There are a lot of candidates to blame the ice ages on. Changes in the Earth's tilt and in the Earth's orbit (Milankovitch cycles) almost certainly play a big part. The chance occurrence of an almost landlocked ocean at one pole and a continent at the other certainly help, but there are a lot of other theories.

One of the niftiest theories is the open arctic ocean theory. It's a variant of one I was taught at school a long time ago. In it, the Arctic Ocean thaws. There are a lot of dry winds up there, and these winds suck up water from the ocean and drop it onto Siberia and Canada. As long as a bit of the snow remains after summer, the snowpiles will, of course, eventually become glaciers and start sliding south.

As water is removed from the Arctic Ocean, warmer water flows in there from the Gulf Stream to keep the Arctic Ocean unfrozen. And so it continues; today's human-induced global warming might be the cause of a human-induced glacial period.

All we need is mammoths again.

And, speaking of mammoths, that's the reason I've included this ice age: I miss the mammoths. Oh, and the ice age seems to have prompted humans to get out of the trees and start building shopping centers.

The big interesting events happened between 13,000 and 10,000 years ago. The last glacial period was well past its maximum. The glaciers were retreating, mostly. (There were ups and downs in the weather, but for the most part things were heading in the right direction.)

Then, rather suddenly, at least three things happened:

- The climate returned to Deep Ice Age levels.

- Mammoths and mastodons disappeared from the world. Other large animals vanished, too, especially from the Americas.

- Humans reached the Americas

Coincidence? Not all researchers are sure about that.

This event is called "The Younger Dryas". Explaining it seems to be a difficult problem. There are a lot more paths to follow and a lot more links than I've provided. Feel free to make up your own theory if you want. Here are some of the major theories:

The Glacial Lake Theory of Climate Change

Well, this tries to explain the sudden drop in temperature, anyway. Here's how it goes. As the glaciers melted across Canada, a huge lake, Lake Agassiz, formed south of them. But the ice was melting, and eventually broke through the ice and flowed into the ocean, probably in a rather spectacular flood.

For years scientists assumed the waters had broken through to the St. Lawrence River valley, flowing into the Atlantic. However, a more recent theory has the water flowing due north along the Mackenzie River valley into the Arctic Ocean.

Scientists seem a bit cagey trying to show how this made such a difference in climate. It probably shut down the gulf stream, and that would be bad for Europe, at least. But for the rest of the planet? Seems a bit much to ask.

Then again, perhaps things were near tipping points. Ice floating on the oceans near the arctic and Antarctic regions may have kept carbon dioxide that was in the water, there, in the water. That kept the world cool. As soon as the ice melted, carbon dioxide could have slipped out of the oceans into the air, raising the temperature and melting more ice, for a feedback effect.

The Space Rock Theory

But there's another contender, and, for once, it isn't a volcano but another space object. Researchers from the University of Western Australia, looking through cores drilled into the Greenland ice cap, found a layer of platinum dating from the age of the Younger Dryas. Platinum, together with spherical particles are, the researchers say, indicators that a space object – a comet or asteroid – hit the earth at the time. If that's just a coincidence, it's a big one.

One problem with the space-rock theory is that nobody's found a crater for it yet. They need one big enough to have thrown enough crap into the air to block sunlight.

On the other hand, researchers from Lawrence Berkeley National Laboratory claim to have found micro-particles such as iron, silica, iridium and nano-diamonds at an archeological site in the U.S. Such particles could have resulted from a massive impact, and the impact may have (they think) killed off the Clovis people as well as some of the large North American animals of the day. The diamonds include a rare type of diamond called Lonsdaleite found only in areas such as meteorite craters.

When I was a kid, the space-rock theory was popular (maybe because it's so simple). What else, an article in the Reader's Digest asked, could explain how mammoths in Siberia seemed to have been flash-frozen, with not even time to digest the buttercup wildflowers they were chewing. Later, people said, well, maybe they fell down into a crevasse and just didn't bother chewing any more at that point.

The Bering Strait Theory

Researchers at National Center for Atmospheric Research in Boulder, Colorado have another take on the Younger Dryas. They believe that the last glacial period was marked by rapid swings of temperature, and imply that the Younger Dryas might have been just another one of these.

The cause? The land bridge between North America and Asia. As water was locked up in ice sheets, the levels of the oceans dropped. It's not all that deep in the Bering Strait, so a land bridge formed. Computer simulations show that if there's a land bridge, the climate is much less stable, and by implication, large temperature swings might result any time melting glaciers dump water into the north Atlantic.

A Shortage of Forbs

Another theory: the big mammals lived not on trees and grass, but on forbs: very nutritious plants such as sunflowers; when climate change killed these off, the mammoths starved. There's no explanation of why forbs didn't disappear and kill off the mammoths during the other 20 glacial-interglacial periods.

The Great Ocean Exhale Theory

Researchers at the Geological Institute of ETH Zurich in Switzerland have noted that, at the end of a glacial period, the oceans exhale a lot of carbon dioxide. That, of course, is going to push up the global temperature. They're not sure why this happens, but they think the carbon dioxide came from deep ocean waters, and winds near Antarctica may have increased, churning the waters to bring up deep water.

Like everybody else (it seems), they're sure the pouring of fresh water into the North Atlantic put a cap on the water-sinking that normally keeps the gulf stream working. With the circulation stopped, the waters near the equator warmed, even the deep waters, which rose as they warmed, hauling their carbon dioxide load to the surface.

A research team from the University of Colorado believes carbon dioxide was exhaled from the oceans in two burps, one 18,000 years ago and another 13,000 years ago. Whether these caused climate change at the time, or were a result of something like the fresh water getting into the oceans is still up in the air, so to speak. Another study claims that the numbers of killer whales was greatly reduced at the end of the glacial period, implying that there were a lot fewer fish around which implies I don't know what, but keep watching for this one.

The Arrival of Humans and the Disappearance of Animals

Well, humans arrived at a lot of places, around the planet, and large animals vanished soon after. North America lost about 72 percent of its "megafauna". Eurasia lost about 36 percents of its megafauna, but then, humans we hunting in Eurasia before they crossed into the Americas. Large animals like Giant Sloths, mammoths, mastodons, saber-tooth cats, and giant beavers were gone not long after people with spears crossed the land bridge into North America and spread south.

Some said that the animals were adapted to cold weather ecosystems and just couldn't take the sudden change. However, remember that there had been twenty or more glacial periods before this last one, separated, in some cases, by up to 16 thousand years of warm weather. In all that seesaw climate change, those animals did just fine, it seems. Up to the last one. Up to the one where human hunters got into the act.

On the other hand, nobody's found any significant piles of bones stacked by humans. In fact, the sites of human encampments show some, but not a lot of, bones of these animals.

And an international team from 43 institutions , led by the University of Copenhagen concluded that different species disappeared at different times. For some, the problem was a loss of genetic diversity, or isolation, or the numbers just soft of tapered away. Ten thousand years after humans came into contact with the wooly rhinoceros, they say, the animals had increased tenfold.

Some theories hold that diseases, brought by humans or their animals, cleared out the animals. I find it hard to believe that there was much long-term effect by diseases. At one time Australians introduced a rabbit plague into the country. It killed 95% of the rabbits, but they rebounded nicely. And Europeans brought diseases that killed between 75% and 95% of the aboriginal population of the Americas. But numbers came back, even if slowly.

A scientist from the Swedish Museum of Natural History, after doing DNA analysis to determine how much diversity there was at any given time, says the mammoths almost went extinct in an interglacial period before the last glacial period began. And that they started to die out 20,000 years ago, when the last glacial period was at its peak. Must have been climate change, he argues.

On the other hand…. A couple of researchers from the University of Wyoming believe the extinction of 35 different genera (groups of species), including mammoths, mastodons, giant ground sloths, were all of different habitat preferences and feeding habits. And that they and many others disappeared rather suddenly, sometime between 13.8 and 11.4 thousand years ago. That, they feel, is too sudden to ascribe to climate change. Must be either human hunting or the impact of a space rock! Actually, they note that this time is pretty well exactly when humans arrived in North America.

Researchers at the University of Tasmania would agree with that. They've looked into the disappearance of 50 types of megafauna (big animals) in Australia. It happened about 41,000 years ago, about the time humans got to that continent.

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Chapter 29: Another Chilly Spell

3,800 Years Ago

It's generally said that for the last 10,000 years humanity has had a lucky run. A warm, stable climate allowed civilizations to grow and flourish. But in the early days, in Conan the Barbarian times, say, there weren't many people keeping adequate scientific records, so some things might have slipped by.

Researchers from Columbia University's Lamont-Doherty Earth Observatory, checking out a glacier in the alps, found that it was bigger twice during the last 10,000 years. One time was the Little Ice Age between 1300 AD and 1850 AD, which is well known.

But they found another period, from 3,800 to 3,200 years ago. Seafloor sediments from off Venezuela show that both cold spells in the north were matched with a drying in the tropics as the rain belt that circles earth's equator moved south.

More than that, nobody really knows. Did those 600 cold years damage civilizations? Or did they ensure that some thrived and others failed? Did they encourage the rise of barbarian hordes moving around in search of food and conquest?

It's a minor hiccup in Earth's history, but as we get into human history, we get more concerned about minor things, since they tend to hit us big-brained apes more than they do the other animals.

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Chapter 30: The Ilopango Volcano

536 CE

I was just watching a History Channel item in the Perfect Storms series called, Dark Age Volcano. It goes something like this:

- Around 536 CE (give or take a few decades – this was the dark ages, after all), a century after Rome fell, something unfortunate happened to the planet, including one of the first big episodes of bubonic plague.

- The date 536 is probably exact because some people around Constantinople (a surviving bit of civilization at the time) noted that for the whole year the sun was as pale as the moon.

- In El Salvador, there's a nice lake called Ilopango that's the caldera of a very large volcano. The fellows in the video were able to date rings on a nearby tree stump to that date. Give or take a bit, as I said.

- The ash around the lake is 4 metres deep, which couldn't have done the local Maya any good at all. They dudes in the video estimate that the volume of ash pumped out of the hole was ten times that of Mount Pinatubo, making it the biggest known eruption in human history, or at least in the last 2000 years.

- Four years later bubonic plague hit Constantinople, killing off lots of people, and almost killing the emperor, Justinian. Presumably, the disease spread over other places, but hardly anybody knew how to keep proper notes. The rough theory is that the dim sun cooled the climate, leading somehow to poor food supplies for rodents (including rats). The rodents, which to this day carry the plague, began migrating, carrying the disease with them. The plague (also known as the Plague of Justinian) hung around for a couple of centuries, but nobody knows how many it killed.

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Chapter 31: And That's Most of It

At this point we pull out of the realm of geologists and archaeologists and into history. The medieval warm period and the little ice age are in some books somewhere.

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Chapter 32: Other Notes and Links

Geological Time Scale

Here's a dandy link to some useful time scales. The best analogy for me is the hand-arm David Schey gives:

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Holding your arms out to your sides; if the tip of your left hand represents when the earth was first formed and the tip of the middle finger on your right hand represents the present, then life first appears on earth about at the bend of your left elbow. From there to about your right bicep, life consisted of single celled organisms, mostly bacteria. At about your right bicep, the first eukaryotes, single celled organisms with nuclei, appear. The first multicellular organisms don't appear until about two inches above your right wrist. The first fish appear at about your right wrist bone, the first reptiles at the center of your right palm, and the first mammals at the base of your middle finger. The extinction of the dinosaurs occurs near the last joint in your middle finger. If you were to take a nail file and make a light pass over the fingernail on the middle finger of your right hand, you would eliminate modern man's time on earth; two passes would eliminate the entire history of hominids, man's entire post-ape-ancestor lineage.

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The Effect of Life on the Planet

As mentioned before, there are a few theories about the way life affects the atmosphere. Here are a couple that I might not get documented:

- Floating plankton that has shells(starting about 300 million years ago) may increase in numbers if the atmosphere's got a lot of carbon dioxide in it. They use the carbon dioxide with calcium to make shells of calcium carbonate. When they die, they drift to the bottom, carrying that carbon with them. This reduces the carbon dioxide in the atmosphere.

- Animals that build coral reefs (starting about 55 million years ago) also take large amounts of carbon dioxide out of the supply to make the reefs of calcium carbonate.

- Grasslands (starting about 8 million years ago) catch fire more easily than forests, and the fire spreads to the forests. They take less carbon than forests out of the air (warming the planet) but reflect more light (cooling the planet). Forests warm the planet by absorbing light, but cool it by producing clouds that reflect sunlight. Grasslands turns to forest if there aren't many large herbivores, and the carbon dioxide levels drop, cooling the planet. Some people have wondered if abandoned farms turning back into forests after the bubonic plague of the 14th century produced the "little ice age" of the next few hundred years. Others have wondered if the slowdown in global warming during the first decade of the 21st century might have been caused by ex-Soviet farms going back to woodland, as the Russians found it more economical to sell oil and buy food than to grow it.

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*** END ***