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Documentary Treatment

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Celestial Mechanics

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In that spring a ship sails into port. Nobody on it is alive. It is controlled by automatic cyber systems. While deep below…

Horror in Clay.

“The most merciful thing in the world, is the inability of the human mind to correlate all its contents. We live on a placid island of ignorance in the midst of black seas of infinity, and it was not meant that we should voyage far. The sciences, each straining in its own direction, have hitherto harmed us little but someday the piercing together of disassociated knowledge will open up such terrifying vistas of reality and of our frightful positions therein, that we shall either go mad from the revelation or flee from the deadly light into the peace and safety of a new dark age.”

“Dead Cthulu waits dreaming…“

Pulp horror writer H.P. Lovecraft penned tales of ancient monsters called Old Ones that, if awakened, would emerge to devour the world. Cthulu lay in death's sleep at the bottom of the Baltic Sea awaiting something to disturb him from necrotic slumber. To learn of these mysteries is to risk madness. For the Old Ones are too awful for the human mind to conceive without succumbing to a hopeless darkness of Bubbling Oceans, Dead Zones, a poisoned planet."

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What if I told you that within two or three years you will die a brutal and horrible death… that your wife and kids will die.That your whole family will be wiped out. Most of your friends, your whole milieu…gone. gone with the new, harsh wind.

What if I told you that your neighbors and friends will turn against you and do this. That the police, and the courts and the military and the government will help them. That your home, and all your possessions will be destroyed. Nothing you see around you will exist. That your entire street will be blown up and burnt to the ground leaving nothing but rubble. That nothing you know will exist as it does this moment. Gone forever.

What if I told you that a madness had taken over your neighbors and fellow citizens and they did this. And then they were destroyed. And their homes blown up and burnt to the ground, leaving nothing but rubble. In fact if you look around, of what you see, nothing will remain.

And all your neighbors will be dead, your city, destroyed. Los Angeles will be flattened, and San Francisco and Portland, San Diego and Seattle. All the cities in the land and all the towns. All major cities, destroyed, lesser ones, too. All roads, rails, airports. The power grid, bridges blown, factories and industrial plants, the infrastructure, the structure of civilization, itself. Leaving wandering survivors searching for food, shelter, heat. And aliens will appear, with power over all.

You would say this is a terrible fantasy. I cannot imagine. I cannot accept. We are a modern society, we have laws, and science and culture. We understand. I am a citizen. It cannot happen. I am valued, respected. I am known. I have an Iron Cross from the Great War.

For this is what happened, in Germany in 1938. Those that could see, those that could imagine, some of them escaped. They made it to America and waited for America to save the world. And we did. But their world…all of Europe, most of the occupied east, the far east and Japan… most of the world was destroyed. leveled to rubble. Ground to dust. Seventy million humans were killed. The world flipped over. Again.

Would you have gotten out? Would you have seen? Would you have believed. Could you have imagined. Could you have acted? Would you have lived?

What if I told you that within a few years you would die a horrible and brutal death? You and your kids. Your family, your friends, others like you. Those unlike you. Those who believe, those who don't. Everybody.

That all you see will be destroyed. Riots, storms, desperation. Armed gangs determined to survive. At any cost. Nuclear war, nuclear winter, starvation pestilence, cold, heat. A world flipped, nature turned against you. A world no longer capable of supporting complex life. And there was nowhere to flee to. No refuge America, northing to be done. But die. And disappear.

And that there was a tipping point but you didn't know where it was. Not a long slide, but a sudden break, giving you no time to adjust. In a few years. Or a few days, Or it was already past. And what you could do is too late.

Could you imagine that? Or do you reject it. Couldn't happen. you say. Or God will prevent. A raptured escape. A heavenly refuge. You abandon this world til it resets. Your marvelous individual consciousness goes on… Maybe. Maybe not.

And this will happen. The scientists tell us it will. And they are scared. Can they get your attention, can you conceive? Can you accept? What will you do?
It is now. What you see around you is a fiction, its a fantasy. It cannot hold. Can you imagine it will disappear. Total destruction. Can you imagine? Can you relate? To the total destruction of your world.

Climate change will reset the world As it has done before. Six mass extinctions that we know about. Many more we don't.You cannot escape to America. It is not that easy this time. This time, it is the whole world. It is humanity. It is oxygen based life down to the single cells. It is the end.

A Petri Dish

The earth is a closed system, admitting only energy from the sun. Imagine a smaller closed system, a petri dish, Imagine it is "infected" with a bacteria, the chemical elements it feeds on and light energy. In the absence of predators, with no limits on reproduction, it will use the energy to rapidly reproduce, to absorb and use all the chemicals, take the energy from them and excrete toxic waste, to fill the dish with its numbers, then to suddenly collapse… to die out, leaving its dead bodies to dissolve back into chemicals. That is the earth. That is where we're heading. We are the infection. That is us. This is my scream.

The climate is like a wild beast. And we're poking it with sticks.
Wally Broecker

The human mind cannot really contemplate the end of its own existence. This is why we created Religion. More so, we cannot contemplate the end of humanity, but it is possible, even likely, and in the long run, probably assured. But what extinction means is the end of all life we know in this part of the galaxy. And we don't know that there is life elsewhere. So it means for us **The end of everything.** But more, the pointlessness of it all. Of all history, culture, experience, our reality. Everything we have known, earned, experienced. All that we have loved, hated, fought against, fought for. All human experience. All the creatures who have shared our existence. All that we have husbanded. All we have known. And it will be our fault. It may be that we will have failed. That the human mind could not advance as fast as our technologies, our moral and intellectual failure. A race to goodness…to godliness. A race that we have lost.

Two hundred million years ago, the Permian extinction destroyed ninety percent of all species and nearly ninety seven percent of all living things. Its origins have long been a puzzle for paleontologists.Geological time is determined by extInction events. Earth resets itself and everything dies. New creatures emerge. A whole new natural order appears …as if a creator had tried again to get it right.

But really it was physics; the balance of being; of taking up energy to reform matter, to create new, different forms from the same primordial star stuff.

A different matrix of life, a new death resetting the world again and again. How arrogant of us to think …it finally it got It right. For the other extinctions have natural causes. This one, as sentient creatures, is on us.

We are smart and rational up to a point. We are the finest and furthest evolved of all and we've figured it all out. We've interrogated Earth and the heavens. We understand quite a lot of the mechanics of life, the rules of physics; how things work. We've even evolved to the point where we can predict our own demise, the next planet slip. And yet in our arrogance and self involvement we don't do anything about it. We understand the great physical forces, but we don't understand ourselves.

There are other tipping points somewhat less than total extinction; the Civilization Crash; a breakdown in the Concordia of Nations, with conflicts, riots, famines, nuclear wars, nuclear winter. With our world at risk, we need more than ever, world cooperation, world coordination, a whole world effort to save ourselves, yet we devolve into nationalism, fascism, tribalism…entropy.

Is this just nature, sweeping the world clean of us, clearing the ground for a new reality, a better-evolving experiment. Is our function really only using up the store of carbon as quickly as possible to deny it to the next iteration of life, so that they will grow more slowly in numbers, permitting a further evolution of the brain? Or is this the natural end-of-life, a Fundamental Limit? Is this, then, the reason why, in searching our part of the universe, we have met no one?

Luxembourg Gardens - Paris[1]

1

"In the early nineteenth century, it became obvious that there had been great catastrophes in the past. But before mass extinction could be recognized, the concept of any sort of extinction had to be proposed and accepted in an intellectual world that for centuries had considered that the creator and his creations were immutable. Once there, they would never go away. It took a great French naturalist to change that.

Limestone buildings line the far end of the park, with busts of the great French geniuses of natural history of the eighteenth and nineteenth centuries.

In one of the halls near the edge of the park there is an incredible boneyard amassed by a father of mass extinction research, Baron Georges Cuvier, the first to draw attention to the concept of extinction by demonstrating that bones of large elephant-like animals found in Ice Age sedimentary deposits could not be assigned to any living elephant. He deduced that these bones came from an extinct species.

The birth of the geological time scale in the subsequent decades of the early nineteenth century quickly demonstrated not only that species had undergone extinction but also that many had done so in short intervals of time. In order to devise some way of determining the age of rocks, European and American geologists had begun to systematically collect fossils as a means to subdivide Earth's sedimentary strata into large-scale units of time. In so doing, they made the discovery that intervals of rock were characterized by sweeping changes in fossil content. Setting out to discover a means of calibrating the age of these rocks, they also discovered a means of calibrating the diversity of life on Earth. They also found intervals of biotic catastrophe, mass extinctions. In a doctrine of catastrophism, these were thought to be caused by a succession of worldwide floods or other disasters that killed off most or all species, followed by a reintroduction or re-creation of new species.

John Phillips, an English naturalist, first to subdivide the stratigraphic record—and the history of life it contains—into three large blocks of time: the Paleozoic era, or time of "old life," extending from the first appearance of skeleton-ized life 530 million years ago until it was ended by the mass extinction of 250 million years ago; the Mesozoic era, or time of "middle life," beginning immediately after the Paleozoic extinction and ending 65 million years ago; and the Cenozoic era, or time of "new life," extending from the last great mass extinction to the present day.

Phillips made the first serious attempt at estimating the diversity of species during the past. He showed that over time, diversity has been increasing in spite of the mass extinctions, which were only "short-term" setbacks. Somehow, after each extinction there was room for larger numbers of species. Far more creatures were present in the Mesozoic than the Paleozoic, far more again in the Cenozoic. But the mass extinctions did more than just change the number of species. They also changed the makeup of Earth. Mass extinctions differentiated the Paleozoic, Mesozoic, and Cenozoic eras.

The Big Five Mass Extinctions

1. Ordovician;
2. Devonian;

3. Permian–Triassic—the “Great Dying”;
4. Triassic–Jurassic;
5. Cretaceous–Tertiary (the K-T).

The Cambrian Extinctions

But what were the causes of these events? Could it have been one kind of cause, repeating itself through time, the way the Black Death returned to medieval Europe every few decades, or were there as many causes as extinctions? Before cause could be ascertained, it first had to be learned how similar in terms of rate and breadth of dying the events were, and quite quickly two very different kinds of mass extinctions were posited, differentiated by that rate. A “gradual mass extinction” would have shown a slow reduction of species over a period of time. Species would have been found over an extensive stratigraphic interval. Long-term climate change would cause this type of extinction.“Catastrophic” or “rapid mass extinction,” would have shown disappearance of species over a short period of time, or stratal interval.

Prior to 1980, all of the mass extinctions were thought to have been of the former type. And there was a second and largely overlooked aspect of the “science” of mass extinction research prior to 1980. None of the hypotheses for the past mass extinctions—such as slow climate change, disease, lowering oxygen, changing sea level, increased predation—were testable. But all of these possibilities seemed reasonable, and all could be seen to be a way to gradually kill off species. Not so for the rapid extinctions. While a rapid mass extinction could be theorized, there seemed no possible terrestrial mechanism to provoke one.

University of California at Berkeley - 1980

Then, out of the blue, in 1980 a father-son team of Luis and Walter Alvarez published a bombshell paper in **Science Magazine**, by forcefully advocating that the K-T extinction was not the consequence of long-term climate change on a multimillion-year time scale, but rather the consequence of a titanic impact of an asteroid with Earth.

The Alvarez group proposed the hypotheses that Earth had been struck 65 million years ago by an asteroid 10 kilometers in diameter and that the mass extinction was caused by the catastrophic environmental changes to air and water in the hours, days, and months following the calamitous, really bad day on planet Earth.

What would have killed everything? Those actually killed by the falling rock would have been limited to a few hundred square miles. But Earth's surface is a lot bigger.

The killer, according to Alvarez et al., was months of darkness from the great quantities of material thrown into the atmosphere. It lasted long enough to kill off much of the plant life, including plankton. With the death of the plants, disaster and starvation rippled upward through the food chains.

A great deal of sulfur was tossed into the atmosphere. A portion reconverted into sulfuric acid, which fell back as acid rain; A killing mechanism, but more important as an agent of cooling with the reduction by as much as 20 percent for 8 to 13 years of solar energy blocked by atmospheric dust…This would produce a decade of freezing temperatures on a tropical world. The prolonged winter is the killing mechanism—and the effect that the giant volume of atmospheric dust has on the hydrological cycle. Precipitation decreased by more than 90 percent for several months and was still only about half normal by the end of the year. It got cold, dark, and dry; an excellent recipe for mass extinction, especially for plants—and the creatures feeding on plants.

How to test this hypothesis? Geological history may be found in the layers of the surface of the earth, exposed where tectonic plates fracture, shear and rise up. Here, history may be read like the leaves of a book. Geologists specializing in geochemistry had to ascertain if mineral and chemical samples from these thin “boundary” layers showed the same evidence. …lots of fossils at constant diversity right up to the impact layer—and then a vast disappearance of both individuals and species.

During the 1990s and the early part of this century, a great battle was fought between those who thought that death had come from above… and those who thought something more complicated was at work.

Peter Ward, University of Washington

Paleontologist Peter. D. Ward, fresh from helping prove that an asteroid had killed the dinosaurs, turned to the Permian problem. In his investigations of the fates of several groups of mollusks during that extinction and others, he discovered that the near-total devastation at the end of the Permian period was caused by rising levels of carbon dioxide leading to climate change. But it's not the heat that's directly responsible for the extinctions.

The Permian extinction, one of five extinctions where the world, nature, our planet earth… reset herself with freakish oceans—belching poisonous gas—the sky;

anoxic; green and hazy. Those ancient upheavals demonstrate that climate change cannot be ignored, lest the world's life …ourselves, face the same dire fate that has overwhelmed our planet five times before.

A Holland America cruise ship. Off Easter Island

Scientist, **Paul Werbos** walks the deck, thinking…[2]

"If CO_2 reaches 1000 parts per million, as seems likely given the limited effectiveness of current world policies, we will probably all die.

I found it amazing that everyone I met fell into one of two groups: (1) those with a kind of religious or quasi-religious conviction that no scientific research about climate could possibly be worth studying further, that "God promised us in the Bible that the world will never be destroyed by fire and brimstone." And two, politically correct and proud people who concluded that they should continue voting for existing policies and research on global warming. But there should not be a systematic world effort to do something new, to get a more precise understanding of this threat; to call for new efforts bringing together paleo-geo-biologists and physical scientists who understand the crucial thermohaline (the temperature-salt content) ocean currents which will decide how soon we fall into "stratified ocean," one of the key triggers for the Hydrogen Sulfide Event?

PART TWO - The Ages of Earth - A Fossil Hunt

The library in the earth, the soils, the material laid down eons ago… You can read it like

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2

a book. Layers of clues, like pages laid one over the other. We find the leaves exposed where the earth has cracked, tectonic plates pushed against each other and breached, revealing a record of flora and fauna from the past. The creatures of one era different, unique but conforming to the same rules of creation, the same physics, the same chemistry, the rules. And we can see an attempt after attempt, a learning program, a technique, a quest to get it right.

“**Mueller Canyon** in Nevada is the best example of rocks clutching one of the five largest mass extinctions… at the end of the Triassic Period…a Catastrophe 200 million years ago blamed on a big rock from space smashing into a world populated by early mammals and dinosaurs, croc-like land beasts, and oceans of ichthyosaurs, ammonites, and strange flat clams. Such dumb brutes could not know that their world was over.

Previous trips to this barren place did not yield the faintest whiff of iridium or glassy spherules or shocked quartz or impact layers so visible in the other known impact extinction at the end of the Cretaceous.” Iridium is a very hard, brittle, silvery-white transition metal of the platinum group, Iridium is found in meteorites in much higher abundance than in the Earth's crust. That is the mystery.

Mountain sheep jumped in fright as we come over the last hill onto the steep slope of our target outcrop; hundreds of feet of Limestone sandwiching a 60 foot thick fan containing a level where the Triassic ends and the Jurassic begins. Another of the planet's stony cemeteries.

The limestones are packed with ancient life; mollusks, Triassic fauna above; Jurassic fauna below. And a band apart. A dead zone. These two worlds show clearly no survivors of some catastrophe grabbing the river of life and giving it a kink to a whole new assemblage; the start to the Age of Dinosaurs after the experimental mucking about in drifting evolution that was the Triassic. Is the system learning at great expense?

Fossilized dead bodies are evidence of mass extinction. Since the discovery of the Berkeley team that the Age of Dinosaurs was ended by an asteroid strike, the geological fraternity has pronounced all mass extinctions guilty from asteroid impacts until proven otherwise. **Now we are not so sure**.

Exonerating the asteroids leaves few suspects. The most likely, rapid climate change and fast global warming brought about by methane and a whole lot of carbon dioxide poured into this world from volcanic smokestacks and deep sea bubbles of poisonous greenhouse gas. One of a series of mass greenhouse extinctions; the rule not the exception; a road we humans might again travel on now, oblivious to the wash out ahead, an accident about to happen one more time or, if we interpret the rock correctly, many more times.

From the top of our outcrop the Valley spreads out. In the distance, the ribbon of road carries a caravan of cars toward Vegas and the chance to roll the dice to hit the jackpot, or go bust… just as the Triassic world bust that meant the death of 60% of all species on earth. And guess what? Our world is rolling the same set of dice.

If there is even the slightest chance carbon dioxide entered the atmosphere 200 million years ago and caused this mass extinction and numerous others… In this case the cry must be “I am scared as hell and I'm not going to be silent!” This is my scream.

Nevada heat was its usual force of death as we set on the remains of a greenhouse extinction. It was not pretty. This graveyard, the evidence is dirty rocks. Is it happening again? Most of us think so, but there are still so few of us who visit the past and compare it to the present and future. Thus the words tumbling out powered by rage, sorrow but mostly fear; not for us but for our children and their’s…

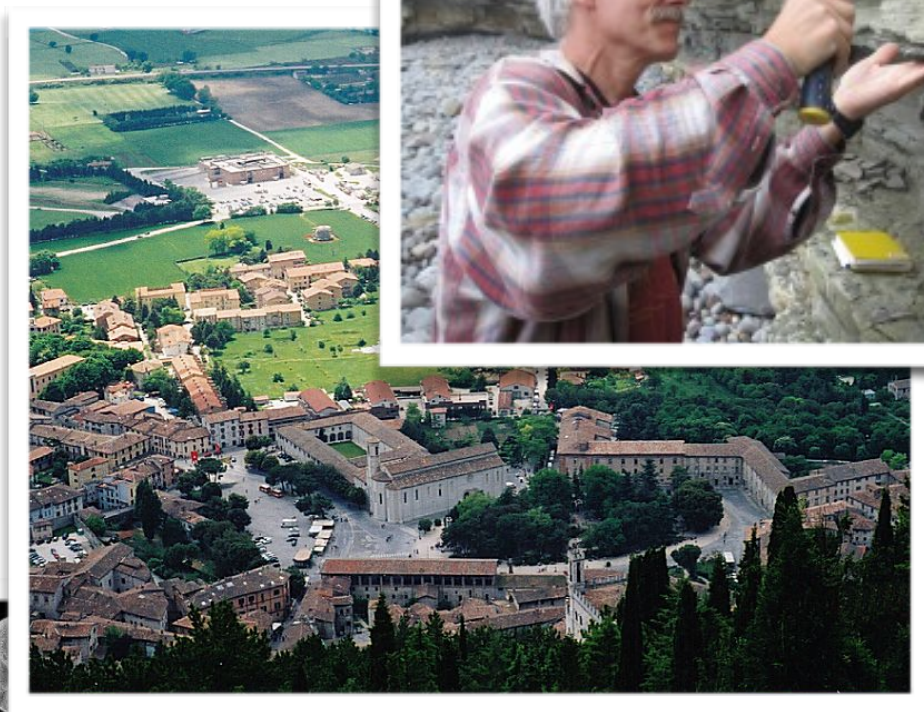
Zumaya - Spain…Basque Country.

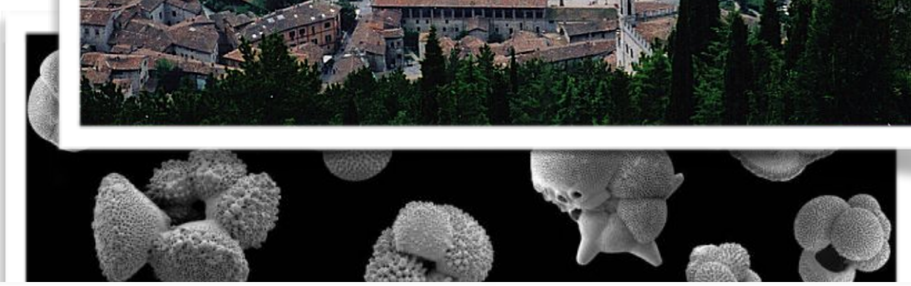
Weidman found no evidence among the Cretaceous period strata of a rapid extinction from an asteroid strike but rather, found evidence that the extinction of the ammonites was the final act of a long slow diminution of diversity that lasted more than twenty million years. The K-T event straddling the Cretaceous and Tertiary periods was a minor extinction at least for the ammonites. The mystery was how the ammonite cephalopods could, after successful existence on earth of more than 360 million years would've gone extinct, while their nearest, look-alike relatives, the still living Chambered Nautilus, had escaped that fate at the end of the Cretaceous.

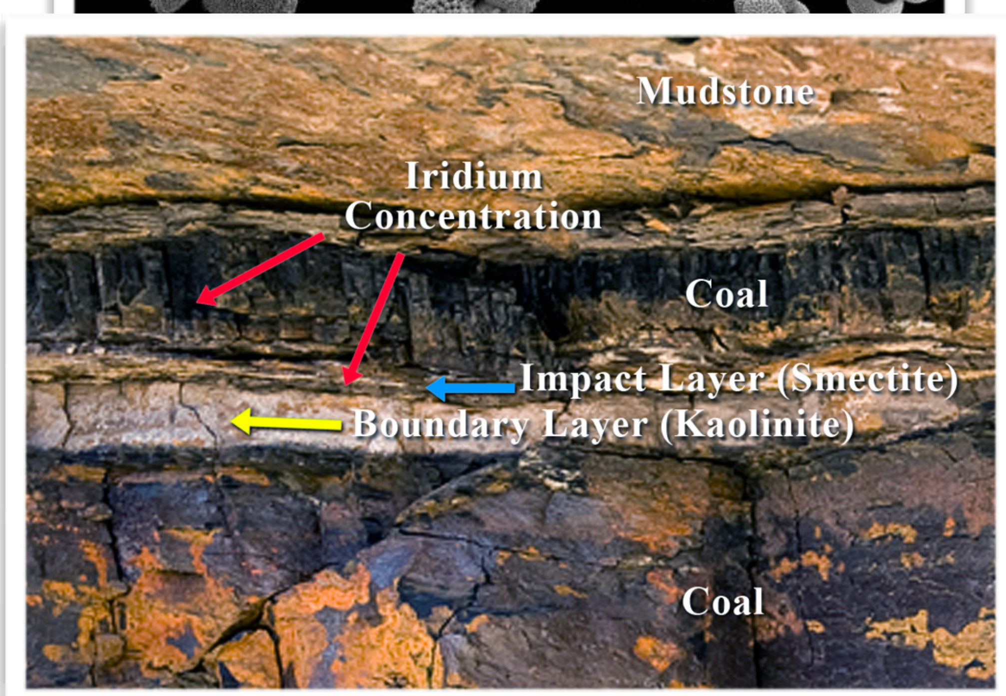
A chance letter to Wiedman led to an invitation to visit one of the few sites on earth where fossil ammonites could be found in stratigraphic sections… the youngest

Cretaceous and oldest Tertiary found in a continuous and well-exposed outcrop.

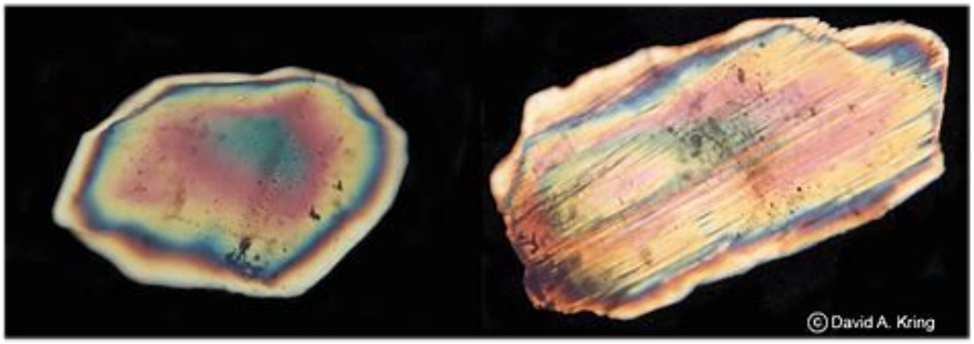
GUBBIO, Italy







Limestone rocks had been deposited on a deep seabed with few larger animals living above, on, or in it. This black sea bottom had untold numbers of microfossils, mainly from two groups. Fossil records of foraminifera and coccolithophorids showed the predicted pattern of sudden extinction. But because no larger fossils—such as the ammonites—existed in these rocks, the major question as to whether the impact, if it



happened at all, had killed off the larger marine animals, from ammonites to clams to fish, to the largest marine reptiles- mosasaurs—let alone the most iconic Cretaceous dinosaurs—could be answered only through the study of other sections.

The search was on for stratigraphic sections, places where piles of sedimentary rock of latest Cretaceous and earliest Tertiary age, could be studied. Sections with the largest variety of fossils available. The best of these in the world were the Basque seacoast cliffs. Wiedmann was the geologist with the most experience in these rocks.

Boundary Bay.

An enormous bedding plane of sedimentary rock, hundreds of feet to a side, an originally flat sheet of strata deposited on a deep bottom 66 million years ago but thrown up some lesser millions of years ago as a consequence of tectonic drift.

Huge walls on enclose the bay with a flat, rocky bench the size of a basketball court exposed at lowest tide. Sheer cliffs rise a hundred feet, each wall brightly colored as if painted by some giant. This K-T boundary layer, was packed with all the hallmarks; the diagnostic iridium, shocked quartz, and glassy spherules.The unusually high abundance of iridium in the clay layer at the Cretaceous–Paleogene boundary gave rise to the Alvarez hypothesis that the impact of a massive extraterrestrial object caused the extinction of dinosaurs and many other species 66 million years ago.

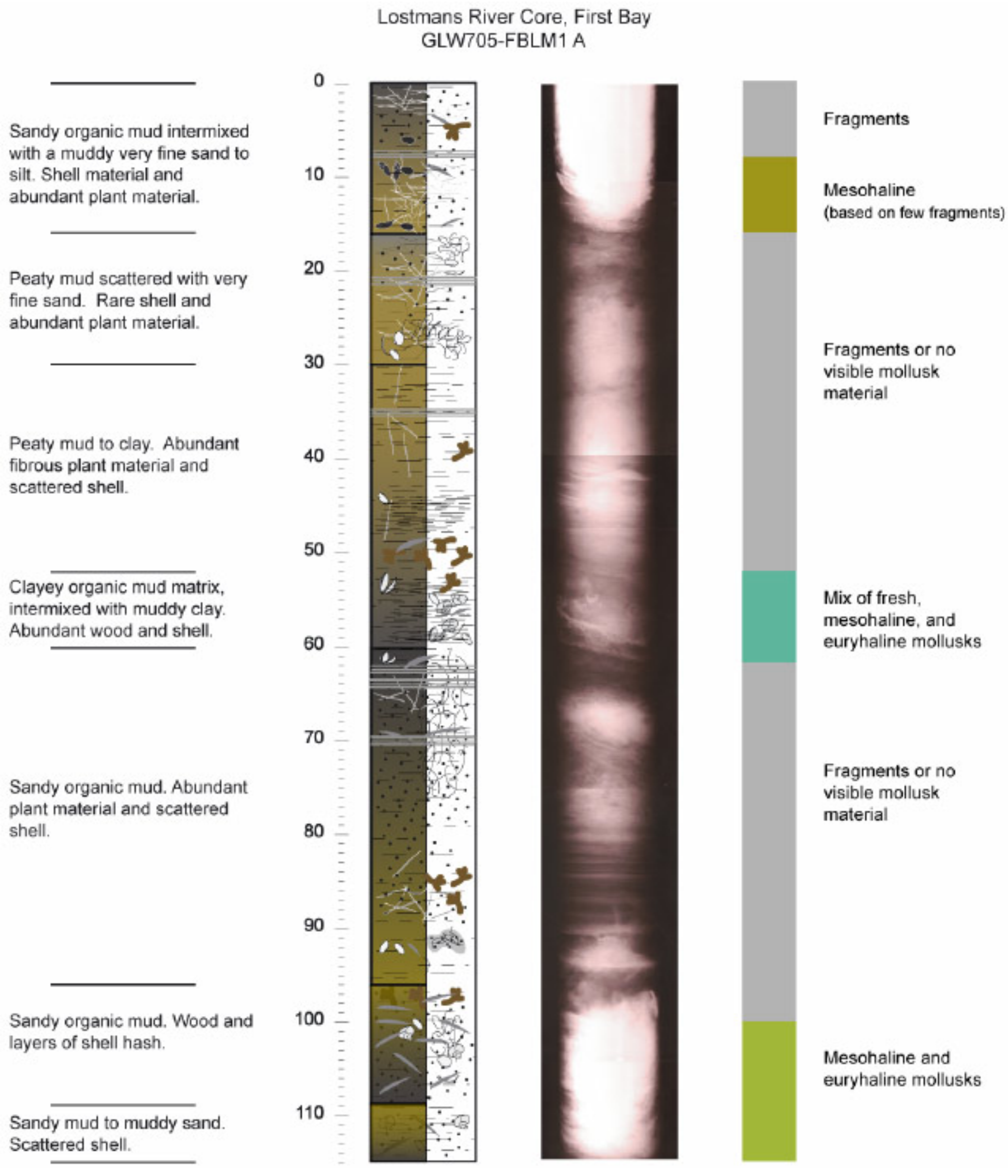
Similarly, an iridium anomaly in core samples from the Pacific Ocean suggested the Eltanin impact of about 2.5 million years ago with each limestone layer representing 24,000 years, alternating with darker shale, all controlled by orbital cycles. The diagnostic iridium, shocked quartz, and glassy spherules, were all in a foot of dark clay sitting between the much more gaudily colored rock layer of before and after. The dark clay seemed an ominous marker, but in reality it was an aftermath, not the calling card of the extinction itself. The rocks above, the rocks below, both were light in color from numbers of calcareous skeletons of microscopic algae in the latest Cretaceous and earliest Tertiary oceans. So abundant were these tiny plants, coccolithophorids, that their skeletons painted the ocean bottoms a bright white, accumulating over the eons into thick white rocks—the familiar chalk.

The chalk seas flourished before the extinction, and after, but not right after. For tens of thousands of years after whatever caused the extinction, the chalk was nearly gone, death removing it from the seas. And in its absence the only sediment reaching the seafloor were small grains of rock eroding from the nearby land. It is this dark rock, bereft of chalk skeletons, that made up the foot of dark clay, called the boundary clay.

We knelt on the wet rock within inches of the uppermost Cretaceous chalk layer. I pulled out a hand loupe, its lens sending a spotlight across the outcrop; a searchlight moving to pick out the star of the show. A thin, red layer of rusty-looking grains grew bold; an eighth of an inch thick, filled with small spheres of glassy material, and fragments of rusted metal. But hidden in this layer at even smaller size were metals even more rare than iron on a Spanish beach: tiny grains of platinum and iridium, the stuff of stars and the asteroids. Such a thin layer to cry out that a world had ended in a crater ejecta bombardment, producing fire and acid rain.

Not just Europe. The impact layer was found in marine strata in Russia, the Crimea, Georgia, along the Black Sea, Japan and New Zealand; along the east coast of North America, into the Caribbean, to South America, all the way to Antarctica. It looked like layers found from land-derived strata, in places such as Hell Creek, Denver, Judith River, the Milk River regions of Alberta, and far into the Arctic. Its calling card was global and easily recognizable; a vast replication of this sequence. As geologists fanned out to study these places, there came a confirmation through replication of fossil records terminating at chemically similar layers caused by the rainout.

Any fossil would be collected from a layer of a known distance below the death layer. This place could be used to test the second of the two hypotheses proposed in the 1980 Alvarez paper: that the fossil record should show a catastrophic appearance,

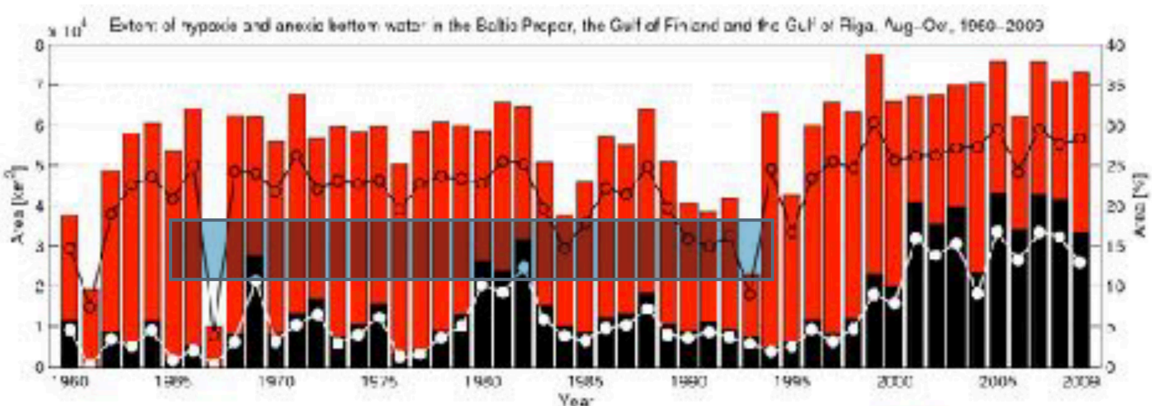


with many species disappearing suddenly from the succession of beds in the layers just beneath the thin impact layer. Wiedmann pondered for a moment.

“I doubt it,” he said. it was his recollection that the ammonites disappeared gradually, not suddenly, because that is how mass extinctions worked. All were gradual.

Whenever a fossil was found, it would have its level below the impact layer noted. With enough collecting one of the major predictions of the Alvarez impact

Occurrence in Current Seas



hypothesis could be tested: Did the ammonites disappear suddenly or gradually? If many species and individuals were found just below the boundary, it would be evidence of sudden extinction. But a long, slow diminution would be a major blow against Alvarez.

Neither of us had been able to find an ammonite within 15 meters of the impact layer. Wiedmann was pleased. Whenever I brought up the Alvarez hypothesis, Wiedmann muttered a deprecation in German. Sudden extinction? Ridiculous. This was becoming the knee-jerk reaction by all but the youngest paleontologists worldwide. To these men there was no way a mass extinction could have been catastrophically fast. Catastrophism was a failed nineteenth-century theory, and none of the powerful, mid-career European paleontologists of the early 1980s—and very few of the Americans, either—were going to allow the field to fall back into believing that failed idea.

Even before 1980 it seemed pretty clear that a large enough asteroid impact would cause a very rapid extinction. Raup was modeling with simple computer programs. He simulated the effects of asteroids of various sizes hitting Earth; hitting this continent or that ocean. Raup watched as his program scythed through Earth's biota. He was fixated on asteroid bombardment as a cause of past mass extinctions,

The impact layers were indeed caused by large-body impact. The discovery of elevated iridium values within the boundary clays and abundant "shocked quartz" intermingled with the iridium. These quartz grains showed multiple thin lines… "'shock lamellae". They have been produced on small sand grains by the explosion of nuclear warheads during underground testing. They are also found in meteor impact craters; no conditions on Earth naturally create such quartz grains with multiple shock lamellae.

Another characteristic was large numbers of beadlike glassy spheres, smaller than a millimeter. These spherules resembled tektites formed by earthly material blown into space during the impact. These bits of rock melted to produce glass spherules, which hit the ocean and settled onto the bottom amid other impact material, the shocked quartz, and tiny bits of iridium.

Fine particles of soot were found in the same K-T boundary clays from many parts of the globe. Soot from burning vegetation. Its quantity suggested that much of Earth's surface was on fire. Carbon is a constituent of life itself. When extinctions occur, the movement of carbon atoms from the living to Earth, and back again, is changed. Early in the twentieth century mass spectrographs enabled geologists to better track the movement of carbon in and out of the ocean, Earth, the atmosphere, and life itself.

The carbon cycle during the great mass extinctions.

Carbon atoms come in three sizes, or isotopes, with slightly varying numbers of protons and neutrons. Carbon-14 decays at a rapid rate that is often used to date particular fossil skeletons or samples of ancient sediments. But for interpreting mass extinctions, a more useful type of information is the ratio of carbon-12 to carbon-13 isotopes, which provides a broad snapshot of the types of life predominant at the time. Changes in the 12C:13C ratio are driven by photosynthesis:

Plants use energy from the sun to split carbon dioxide into organic carbon, which they use to build cells, provide energy and free oxygen; their waste product. But plants are finicky, and they preferentially choose CO_2 containing ^{12}C over the slightly larger (by one neutron) ^{13}C isotope. As a result, a higher proportion of CO_2 remaining in the atmosphere contains ^{13}C when plant life is abundant on Earth—whether in the form of photosynthesizing microbes, floating algae, or tall trees—and atmospheric ^{12}C is measurably lower.

But plants are not the only organisms that employ CO_2; the formation of a clamshell, involves the precipitation of calcium carbonate, requiring carbon atoms. Clams use both isotopes, but if a mass extinction had swept away most plant life, thus reducing photosynthesis, all clams in the new, deader world would have encountered a greater supply of ^{12}C. This information is incorporated into their skeletons, from before, during, and after a mass extinction, a reliable indicator of the amount of plant life both on land and in the sea.

For the K-T event, the carbon isotope curve shows a simple pattern. Simultaneously with the impact layer containing impact debris ; iridium, shocked quartz, and glassy spherules, the carbon isotope pattern shifts—more ^{12}C is present relative to ^{13}C—for a short time, and then returns to its old, pre-impact values. As if a large amount of Earth's plant life, both on land and in the sea, was suddenly killed off, was dead for a while, and then came back to life.

And it is consistent with the fossil record: Both land plants and the sea's microscopic plankton underwent staggering losses in the K-T event. For a short period, there must have been a worldwide and devastating extinction of plants. Forests burned to the ground, plants not killed were subjected to changes in temperature and water. Under a blanket of cloudy debris from the smoldering crater, earth cooled for decades, and the tropical vegetation of the steamy, hothouse Cretaceous period froze to death It was a single, neat record: bang, change, return to normalcy—except that most of the plant and animal species characteristic of the pre-impact period were gone.

All of this evidence provided comfort to the Alvarezes and their supporters. Dinosaurs, death, asteroids, everything but alien sex..But massive reputations and egos were at stake. In the mid-1980s the non-impacters counterattacked.

Around the time of the K-T extinction, a large area of what is now India slowly became covered with lava, becoming a “flood basalt.” Many flood basalts are visible today. In Washington State, Oregon, and Idaho, an enormous area is black basalt hundreds of meters thick. All of this lava oozed out to cover hundreds of square miles. It came not from volcanic cones but from great cracks in the land itself. Flood basalts produce more than just lava. As magma rushes out, it carries enormous volumes of gas including hydrogen sulfide, methane and carbon dioxide. If flood basalts are combined on a global scale with explosive volcanism that throws great quantities of ash and dust into the atmosphere, one might expect major effects.

It became clear that there could not have been enough volcanoes on earth to produce the amount of iridium found in the K-T impact sites. But in one area, the volcanic side had found a relationship between volcanism and mass extinction.. Geologists using new dating techniques to look at flood basalt were surprised at how large some of these provinces were. Paleontologists finally had confirmation of the second part of the Alvarez hypothesis; the impact did indeed cause the mass extinction. We came to understand what impact extinction acts like. Like an earthquake hitting a city. One moment everything is normal, the next all is calamity.. One day the Cretaceous world was living its life; the next it was destroyed, the deaths coming either that day or in the weeks, months, and years afterward. But one thing is sure: Recovery starts immediately. When the aftershocks finally still, the rebuilding starts.

The view that impact was a cause not only of the K-T but also of others, or even all the mass extinctions, began to appear. If it could happen once, why not other times? The Alvarez hypothesis transformed into a larger entity: Mass extinctions were always the result of asteroid or comet impact. This became the new paradigm, and it has held ever since. Till now.

Southern France - Tercis-le-Bains

The blinding white quarry near the mineral bath resort town is tucked up against the foothills of the western Pyrénées, near the Bay of Biscay. Its strata were deposited in the same basin as the K-T sites at Zumaya, Sopelana, Hendaye, and Bidart, places that had played such a large role in the K-T controversy. But the Tercis site had accumulated its strata in very shallow water, compared to the deepwater sites on the Biscay coast, and it held a wealth of shallow-water animal fossils. The abandonment of the quarry, mined for its pure white limestone, was a godsend to geologists. The last 10 million years of the Cretaceous period were found there.

“Could All Extinctions Be Caused by Impact?”

Raup, and Jack Sepkoski, identified the period. Every 26 million years, it seemed, a mass extinction occurred. But what could cause such periodicity? There had to be some celestial rather than earthly cause. Astronomer Rich Muller postulated that a faint and overlooked companion star to our Sun - Nemesis- caused there to be heavier-than-normal asteroid flux crossing Earth’s orbit every 26 million years.

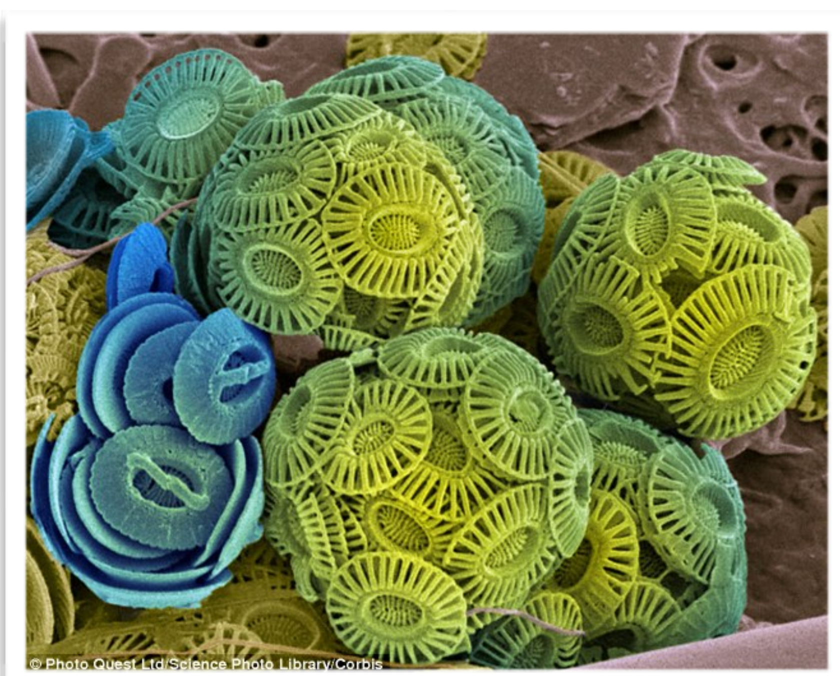
While most paleontologists searched for evidence of impact, paleo-ocean -ographers, were retrieving data of a different kind, data explainable in only one way. That had nothing to do with impact; a discovery supporting a very different paradigm—that Earth’s contents drifted over the surface through plate tectonics.

The Glomar Challenger carried oceanographers and geologists to every corner of the seven seas, to extract deep-sea cores with K-T boundaries. But the one place that the drill ships had difficulty in were the high latitudes of the Arctic and Antarctica, places where the brutally harsh weather conditions made drilling next to impossible.

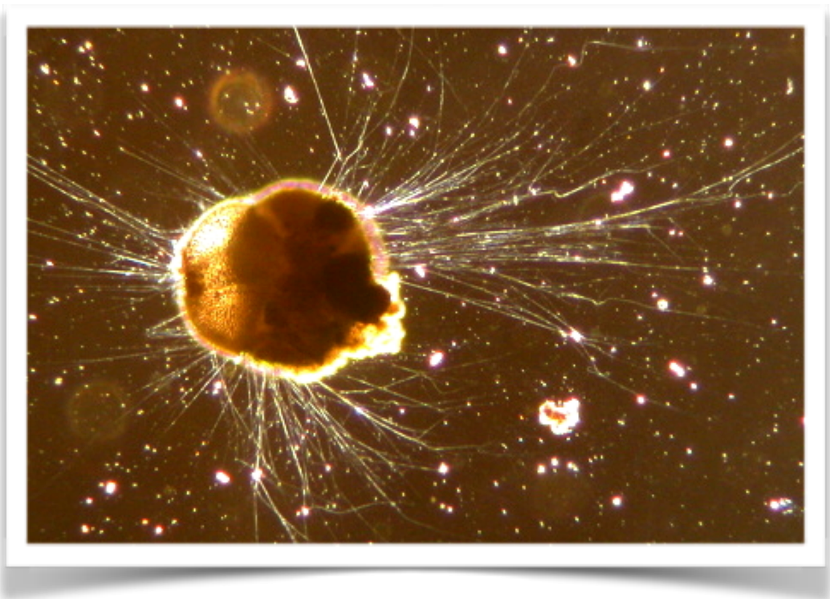
With another ship, the Resolution, scientists finally were able to penetrate the ocean bottoms near the poles. A voyage called Leg 113 was to sail Antarctic waters, where a team that included renowned microfossil paleontologist Jim Kennett of Santa Barbara and Lowell Stott, began retrieving cores of strata with K-T boundaries obtained from drilling yet another hole through the K-T boundary, and the phenomenal expense of this kind of work really stimulated the crew to try for something new.

Two cores were especially interesting to them. ODP 689 and ODP 690, the former of strata deposited in deep water in the ancient ocean and the latter from much shallower water. This turned out to be crucial.

While Kennett was trained to identify the microfossils found at the bottom, mainly of foraminifera…amoeba-like protozoa with a shell…as well as the smaller and plantlike coccolithophorids, the analysis of isotopes of carbon and oxygen can be extracted from



the tiny fossil shells in the cores. Carbon is not the only element whose isotopic differences can be used to great interpretive effect. Another is oxygen, with isotopes of O_{16} and O_{18}. The lighter isotope, O_{16}, is far more plentiful, and like carbon, the isotope ratios can be recovered from samples of clamshells or bone.



The variance in the ratio of O_{16} to O_{18} has nothing to do with photosynthesis, however, but instead is related to the temperature of formation of the carbonate mineral trapping various oxygen molecules. In warmer settings, less O_{18} is taken up in the mineral, and with cooler environments the opposite occurs, a virtual geo-thermometer. The first samples run through the machines were from the K-T boundary parts of cores 689 and 690, and they yielded unsurprising results. Like those already found from other K-T boundary sites, the results from these deep-sea cores showed a pattern: They suggested that an extinction among photosynthesizing organisms had taken place.

The Carbon isotope record across the Paleocene-Eocene boundary cores showed a short-lived negative excursion. Plant life is reduced; the hallmark of mass extinction looking at benthic organisms - bottom dwellers- found evidence the Catastrophic mass extinction on the bottom; more sensational because the same creatures had suffered little the K-TM extinction. Was it simply warming of the deep ocean, with a cold adaptive species?

Sixty million years ago the Benthic species died out. Not dinosaurs suddenly going extinct in fire and brimstone. Not rising temperature in the great depths, but falli ng oxygen levels on the bottom caused the warm water to become entrophic.

The K-T event killed plankton, but left the deep warm bottom waters where evaporation made them saltier and denser. This is a transport along the sea bottom like a conveyor belt even as far as the cold, high latitude sites of the Paleocene age. Today conveyor currents run from the tropics to high latitudes. Cold oxygen-rich water sinks to the bottom, then flows back to the origin. Many of these benthic forms died out quickly in an event that lasted 400,000 years, but did similar event happened on land?

Wyoming's Bighorn Basin

The pattern of carbon and oxygen isotopes in rocks show a mass extinction the same time on land as in the sea. The reset was the start of our modern mammalian marsupials, herbivorous, ungulates, insectivores, primates.

Dust levels decreased. With the sudden global volcanic activity 58 to 56,000,000 years ago the difference in temperature from the equator to the poles changed marke dly. The heat exchange slowed, reducing the number and ferocity of storms. The world wind calmed. Very hot explosive eruptions of flood basalts, increased carbon. dioxide in warmed oceans contained less oxygen. Deep sea forms used to living in cool, highly oxygenated water found themselves in the hot poison and died out.

El Kef - Tunisian Southern Desert - White limestone hills.

A Million years ago the middle Cretaceous period first shows flourishing flowering plants in the wall before, at a hundred foot height, a six foot thick layer of absolutely black rock sandwich. Black is death.

Italy's Umbrian Appennines - The Bonnarelli Bed
Chalks of England
Shales of Wyoming
Lime limestone's Colorado
Offshore turbinates of California

Cream salt stones of Alaska Matanuska Valley

Queen Charlotte Islands- British Columbia

Everywhere, the same message: death and extinction, a world strangling in the Cenomanian - Turonian event. The switch is strong and black death records oxygen free water asphyxiating inhabitants of the bottom. The entire ocean went stagnant,

currents stopped. Organic matter settled onto the bottom, devouring oxygen. With no oxygen coming down to replace it, this shows anoxia; mass extinctions explained.

Caledon River - Great Karoo Desert, Orange Free State, South Africa

The Permian
“The Great Dying” or the Mother of All Mass Extinctions.

I kept heading up through time, While fossils had been common on the Caledon,

in beds deposited a million years before the Permian extinction, they became rarer at the end of the Permian, 250 million years ago. so different from the fossil record at many K-T boundaries around the world. The Cretaceous fossils remained common and diverse right up to the K-T impact layer with its overlying boundary clay—and there they simply disappeared. In these late Permian rocks, vastly older than even the Cretaceous, it was as if the world had been slowly dying over a considerable length of time. There were many possibilities for this: Perhaps the way these large land animals had died and become entrapped in sediment, to fossilize and rest a quarter of a billion years had changed. Perhaps rivers had dried up, and the traps for bones disappeared. But perhaps the animals themselves gradually became rare, as some long-term hand slowly but inexorably closed the windpipe of a living Earth to a death experience.

In spite of the near absence of fossils, I began to search for bone, and more began to appear along both sides of the creek bed. Bone, jutting from the olive-colored sedimentary rocks; visual cues: colors, textures, shapes that would subtly call to eye and mind. I looked up: Large buff sandstone cliffs a half mile distant, and the red beds of Triassic age, while the greenish rocks were definitely Permian, If that was Triassic up there, then somewhere ahead, had to be rock that had accumulated in swamps, lakes, ponds, but mostly in river valleys during the time of that long-ago cataclysm.

A few broken, eroded, but unmistakable fossils of the last Permian animals, not articulated skeletons, but isolated bones and teeth. A large scapula, probably from the most common and characteristic animal of the latest Permian, the large, cow-like Dicynodon; there a tusk of another Dicynodon; and most sensational, the broken tooth of the most fearsome carnivore of that long-ago world, a gorgonopsian, or Gorgon.

Permian, Permian, Permian, the rocks whispered to my increasingly addled mind, the heat insignificant compared with that at the end of the Permian period but hot enough to make a human brain wander, to lose focus and capability. Eyes down as more and more outcropping began to appear along both sides of the creek bed, I rounded a corner of the walled gulley and nearly died of a heart attack as three elk-sized, long-horned gemsboks startled into flight, leaping upward to scramble out of the gully, flailing legs scr The burst of adrenaline spurred was dissipating, lassitude returning, only an hour till pickup and camp. Idly looking down at the rocks I sat on, I absentmindedly watched the purposeful ants marching to and fro before I focused on the ants' freeway. The ant-covered sedimentary rocks were strangely colored compared with the strata that had been present all afternoon.

Not the drab olive of the Permian or the bright red of the Triassic, but an anomalous candy-cane assemblage of both. Curious, I followed the strata to the gulley wall, to be immediately confronted by a beautifully clean rock surface, obviously scoured annually by the flash floods of the Karoo.

The thinly striped alternation of red and olive was even more pronounced here,, beds clearly laminated. Beds known to be preserved only in the absence of life. All the beds originally were like these, but soon after their formation, ancient, Permian armies of insects, nymphs, worms, crustaceans, and the shuffling feet of the larger vertebrates visiting the shallow ponds and waterholes, destroyed the fine laminar bedding, churning it into a mass mixed mud of one color and devoid of any layering at all.

I climbed upward, toward the sandstone hills. Climbing into younger parts of the sedimentary strata. A few feet above the striped rocks, the characteristic red mudstones with small white limestone nodules characteristic of the Triassic, and a skull of a small Lystrosaurus confirmed that this was the lowermost Triassic.

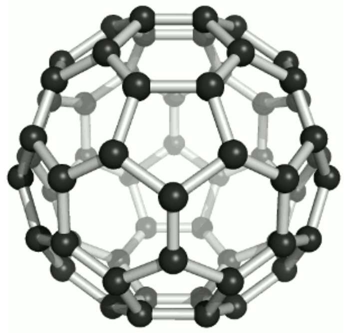
Higher into the Triassic strata I entered a fossil hunter's heaven: first tens, then hundreds, of bones, showing a characteristic blue-white color amid the red rocks, all from the pig-sized mammal-like reptile, Lystrosaurus, the index fossil that characterizes the earliest times after the Permian extinction. After the long days of searching the Permian, with its beds so barren, it was joy to be amid such treasure. But these fossils told little not already known. They were all of but a single species rather than the more than fifty in the beds below. No one had been able to find evidence of impact so clear in both marine and land deposits of 65 million years ago, the dino-pocalypse, when 90% of all species disappeared, but how fast?

Meishan, China

At scattered ash layers, an environment of the seas at the end of the Permian. Over three hundred species of marine life, evidence of deep sea extinctions told suddenly in red tides. Evidence of global warming with Siberian lava eruptions at the same time…many levels of extinction in addition to this catastrophic level; as if there had been a series of catastrophes, one big, many nearly as big.

One theory is "Murder on the Orient Express". Multiple stresses combined to cause the mass extinction. But this calls for 165,000 years of action when the K-T die off was perhaps just decades. Of the potential causes of mass extinction only one has an impact capable of causing such mass death in so short a time.

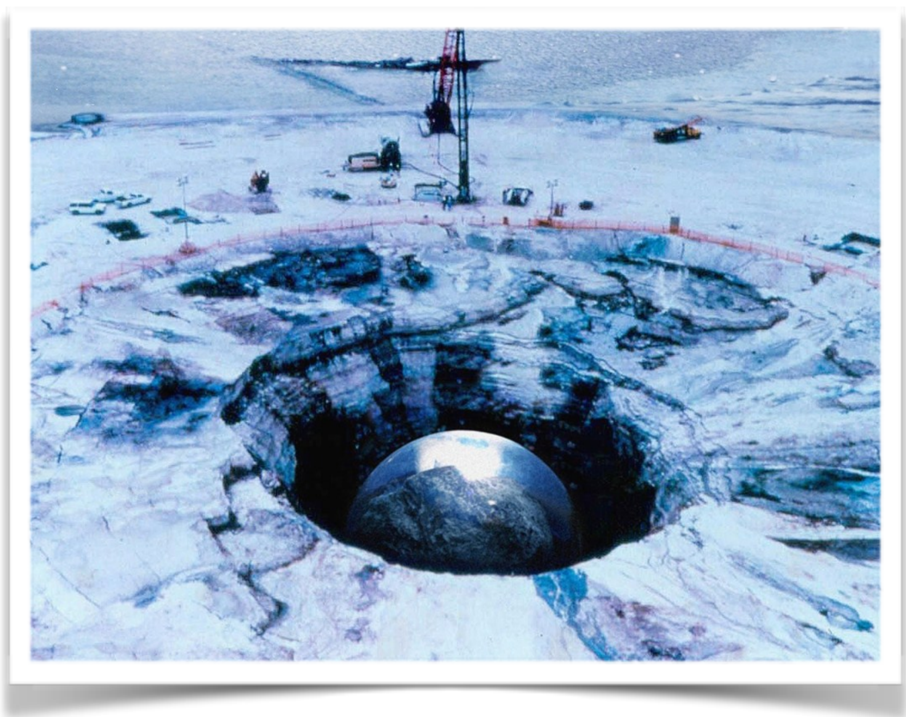
The Permian included evidence of oceanic anoxia, but no hint of excess Iridium, no indication of asteroidal impact. so… What was the culprit?



Buckyballs.The latest Permian boundary showed high levels of these complex carbon molecules; buckminsterfullerene's were buckyballs with helium trapped inside the cage structures.

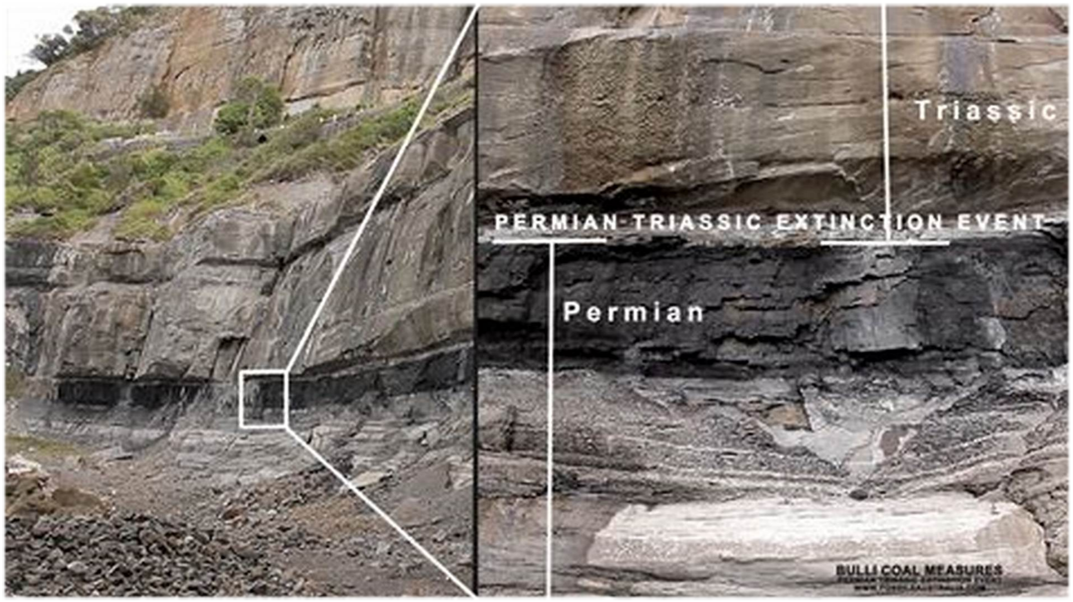
Extra-terrestrial helium is mostly helium3, an isotope not found on earth because it is blocked by the atmosphere and the magnetosphere; striking evidence Earth been slammed by a comet at the end of the Permian period. Fullerenes were found at very low concentrations above and below the boundary layer at the two sites, but they were found in unusually high concentrations at the extinction.

A large structure far beneath Antarctic ice was probably “the” Permian crater—but really bad science, since they could not confirm the large structure, detected remotely using gravity anomaly measurements. So, by the middle of the first decade of the new century, the riddle of the Permian extinction was solved by the discovery of non-replicable helium-3 findings from a non-crater.



The Early Triassic was a time of heightened methane gas in the atmosphere. Methane is one of the most potent the greenhouse gases. Release would've driven global temperatures sharply higher. These results followed findings from the Sydney Basin in Australia. The P-T boundary was coincident with the formation of coals. The boundary coincided with a large-scale extinction on plant species, a dramatic change over in fossil soil types indicated a much warmer climate, the sudden onset of global warming. Coal formation shows a sudden deforestation at the P-T boundary.

Clearly a single impact could not of been responsible.Interpretations are repeated perturbations such as methane hydrate melting pulses, repetitive overturn of the stratified Ocean persistent with volcanic exhalations. The Permian and Precambrian times each ended with large-scale swing ratio of carbon isotopes in a mass extinction, suggesting the oceans of the late Precambrian era were stratified, water with more oxygen on top, below, large amounts of organic material in sediments.



This pattern changed so that deep water which had been safely locked away began to liberate its load of dissolved carbon back into the shallow waters, then into the atmosphere. Large bubbles belch fourth as if the the oceans are one big soft drink.

Lake Cameroon - Niger, Africa.

As thousands of humans and livestock sleep, the surface softly erupts and hisses.. The bubble of carbon dioxide, moves inland, a blanket of poison killing those animals and humans. The same mechanism happened at the end of the Permian. The sudden increase in carbon dioxide killed most marine species. But how?

The P-T boundary shows a succession of death intervals spanning a few million years before and after the K-T boundary; isotopic evidence that a large plant-filled world went suddenly dead, remaining so for tens to hundreds of thousands of years. The die off brought a glut of carbon 12 that had been tied up in plants. Rapid catastrophe, followed by repair of the eco systems and replacement of species by the evolving new growth. Things healed rapidly. But in the late Permian and Triassic, at the P-T boundary, there was a succession of perturbations, with recovery cut short in between. A boxer constantly knocked off his feet, staggering upright, but never completely knocked out. What could explain this?

The Queen Charlotte Islands, British Columbia - Choppering into Jurassic

An isolated archipelago, an outcrop of rocks spanning the Triassic - Jurassic. Whatever caused it, the extinction was enormous. More than 50% of marine animals died. Prior to the extinction the land world harbored a great bestiary of exotic reptiles and a few mammals. crocodile-like forms, herbivores, primitive dinosaurs… after the extinction everything died out but the dinosaurs. In absolute numbers of species killed off it was the biggest of all extinctions.

Were the same isotropic perturbations observed at the end of the Cretaceous, Paleocene and Permian time intervals? Were there perturbations but also, what kind? Was it a large change in the carbon isotope ratio as we had found after the K-T catastrophe; the surface plankton was destroyed but the deeper organisms remained unscathed? Or was it the heavier carbon from the Permian and Paleocene? So far the results were gibberish.

SEATTLE - MASS SPECTROSCOPE

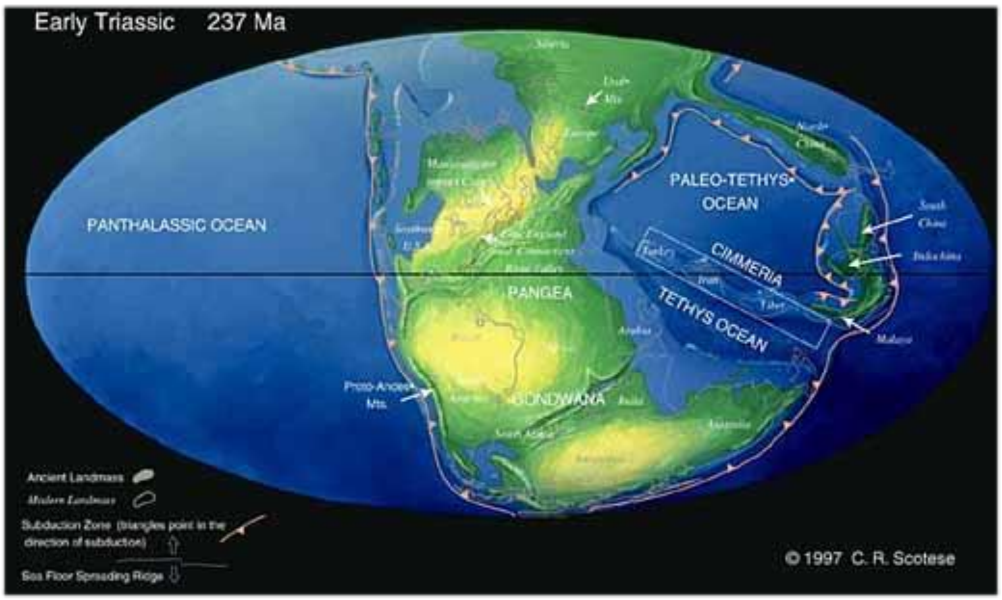
If the carbonized symptoms showed a Permian pattern it would be strong indication that Triassic extinction was similar to the Permian extinction; that neither was caused by impact. A single isotope perturbation would be a vote for impact.

The first perturbation was right at the boundary, but then there was another one, going in the opposite direction, followed by another negative excursion. Extinction, rebound, second extinction. This was a Permian-like signal.

Newark Valley - New Jersey - Late Triassic and Early Jurassic dinosaur footprints

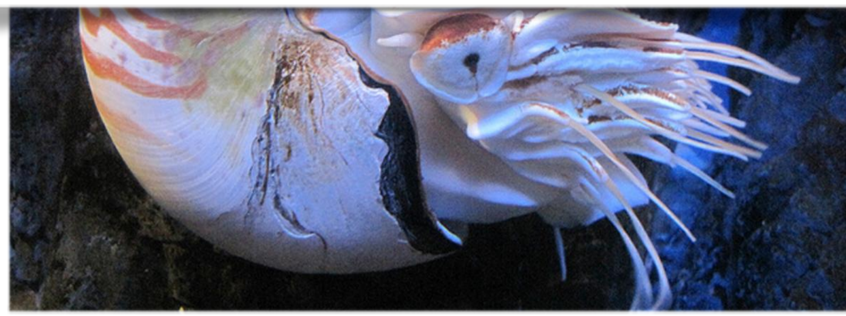
Sediments from the great rift valley formed when Europe split away from American in late Triassic time..evidence of impact at a new T-J site. Rather than killing off the dinosaurs it acted like dinosaur fertilizer. Right after the hit there were more and bigger dinosaurs. At the palisades, not sedimentary rocks but giant heaps of frozen lava. The Triassic ended in a paroxysm of volcanism spanning the Central Atlantic

magnetic province, a flood basalt deposit stretching from Brazil to the Bay of Fundy…an exploding carbon dioxide world just as an asteroid hit. Here at the end of the Triassic was a major volcanism coincident with the great mass extinction , not just in the sea but with land animals as well. The true cause of these extinctions would be scattered not only in ancient fossil record as well in the ocean and its current inner volcanoes and even in noxious lakes and ponds in Micronesia. Was there a new paradigm for mass extinction?



BRITISH COLUMBIA

Ammonites of the upper layers. That showed K-T was not a gradual but his sudden extinction. On this beach in British Columbia just the opposite pattern showed. Meter by meter the number of kinds as well as the sheer number of ammonites dropped. But near the top of Fredrick Island were rocks packed with fossil clams, The



ammonites gradually disappear to total extinction, But their extinction occurred a hundred stratal meters below the end of the Triassic.

Palau Micronesia

A large cage full of nautilus. Attaching transmitters to their shells, found that they were not surface creatures but live at the depths. At the end of the Permian-Triassic, deep water animals fared worse. Shallower forms did better. At the end of the Cretaceous, just the reverse. Shallow water fauna was almost exterminated; plankton as well as animals. Deep water forms, the diadems and nautiloids, came through unscathed. Researchers studying the asteroid impact came to the conclusion that the surface of the sea down to 100 feet would've been lethal to most of its inhabitants, due to a combination of high acidity and toxins falling from the sky after the titanic impact. The ammonites lived up there, bred there and, at the end of the Cretaceous, died there. Yet in the other mass extinctions just the opposite held true. In the Permian and Triassic events, the deep was more lethal than the shallows.

We dived in a large, stinking fresh water lake in the interior of the island. Masses of jellyfish floated in the clear surface waters. But this was a thin stratum atop a very different water mass. Below was a place with no animals for it had no oxygen.

What did have was a deep purple color and rising from the layer of far more primitive life were small bubbles of a toxic gas; hydrogen sulfide.The bacteria was of two kinds and both used sulfur in their system. Both needed sunlight as well, but they could not live in oxygenated water. One was purple in color lent its color to the bottom water. Amid these were green bacteria and they too were metabolizing Sulfur.

But a third kind of bacteria was here as well; invisible to the naked eye. They

produce hydrogen sulfide as waste of their metabolism. Only a thin layer of oxygen water kept them from coming to the surface where they would receive more light, grow faster and release poison directly into the atmosphere.

This would become known as a Canfield ocean: highly toxic, saturated by hydrogen sulfide. Geologist Don Canfield discovered that before the rise of animals oceans were chemically and biologically different from the oceans of today and were highly-saturated by toxic hydrogen sulfide. Our ocean, saturated with oxygen from top to bottom is chemically different and far more benign to animals and most microbes. These strange lakes would help answer the question of different fates of the ammonites and the nautiloids and would radically alter our understanding of mass extinctions.

This was the end of the Palau Drop Off. Here, in the early 1990s massive lethal low-oxygen water would rise from the dead and kill all the corals. Very warm water generated by global warming… first of the shocks in the oncoming greenhouse extinction…one of the first clues, a dead zone…coral bleaching.

By 2005 the geological and biological detectives knew what did not cause the Paleoscene Triassic, and the immense Permian extinction. But if the cause was not impact then what? And how could slow climate change kill so many species? With slow warming, species would just move toward the poles. So a new idea was needed.

Microbiologists studying bacteria found in the jellyfish lakes of Palau discovered that bacteria left records of their presence in sediment. Green plants using photo-synthesis leave behind distinct compounds as do various microbes from other environments. A new kind of fossil was discovered. Scientists begin to extract organic residues; chemical fossils known as biomarkers; evidence of long dead life forms that did not leave skeletal fossils; but traces of distinctive lipids or fatty molecules from their cell membranes.

With Gas Chromatography Mass Spectrometers scientists found microbes living in water high in light, low in oxygen, and high in hydrogen sulfide. One organism, photosynthetic purple bacterium, for energy takes sulfur compounds and oxidizes them. These creatures coexist with more noxious cousins; bacteria that produce hydrogen sulfide; nasty, toxic stuff most life avoids. A new paradigm for mass extinctions; great numbers of this nasty bacteria, near the end of the Permian, was involved in mass extinctions both on land and sea.

Under unusual circumstances anoxic conditions below the surface permit deep swelling microbes to churn out a copious amounts of hydrogen sulfide which dissolves into the seawater. As concentration builds the gas diffuses upwards, encountering oxygen diffusing downward. So long as their balance remains undisturbed the waters r emain separate with a stable interface known as the chemocline. But if oxygen levels drop, conditions favor the anaerobic bacteria. Beyond some critical threshold, the chemocline fails, great bubbles of highly poisonous hydrogen sulfide gas rise into the atmosphere; a planetary killing known as the Kump hypothesis.

The same process may have occurred at other times in Earth's history; might have caused the mass extinctions. This would interfere with the ozone layer and sediments show living things being damaged by ultraviolet light. The loss of the ozone layer, the emergence of hydrogen sulfide from the seas would have coincided. An abrupt increase in both carbon dioxide and methane significantly amplifying green house warming, carbon dioxide pouring out of the volcanic eruptions. And hydrogen sulfide becomes more lethal as temperature rises.

Kump's group looked for the distribution of hydrogen sulfide commission around the globe they used a global circulation model originally developed to understand whether and climate but because the positions of the continents as well as temperature of oxygen and carbon dioxide levels we're known for the critical end of the Permian the method could be applied to look for areas with high erosion rates for phosphorus bearing minerals. Phosphorus is a primary component of fertilizer. Sulfur microbes would've thrived with an abundance of it. If the sea level dropped, phosphorus would be exposed and an erosion would've dumped it back into the sea.

Washington DC 2005 - NASA Meeting

Kump presents his findings. A slideshow - The ancient Permian world oceans.

The oceans are accomplices in the poisoning of the world; as if over-abundance of hydrogen sulfide did not happen only once but occurred over and over as a succession of burps clustered around the time of the PT boundary. The most ominous note: not only did the model show where hydrogen sulfide would emerge, but new calculations corroborated earlier estimates of how much hydrogen sulfide would have gone into the atmosphere. There would have been more than enough to kill off most land life. As the nasty stuff came out as bubbles there would be high levels dissolved in shallow seawater where it would have been lethal to shallow marine creatures as well as shallow water organisms that secreted calcium carbonate skeletons such as corals, clams, brachiopods and bryozoans; all invertebrate victims of the extinction.

Bainbridge Island

A 30 million year old outcrop from the Oligocene epoch shows an abundance of life in an ocean similar to ours today. With oxygen levels the same at the bottom as the top, as has remained the case ever since, the abundance of life on the bottom confirms the oceans were animal-friendly from top to bottom.

The main drivers that created this mixed Ocean where the extreme temperature differences that still exist between the cool polar regions and the tropics. When there's warm surface areas and cold surface areas of the ocean, cold water flows towards the warm and vice versa. But more than surface currents accomplished this. Cold water is denser than warm water of the same temperature. And sinks. Saline water is denser than less saline water of the same temperature and also sinks. In the heat of the tropical sun, water rapidly evaporates making the surface saltier and denser. In the Arctic the melting of ice adds water to the sea making it fresher. All of these factors create sea water bodies of different temperature and salinity that want to mix with others of different values and in so doing produce conveyor currents throughout the world oceans. But this kind of Ocean is a relatively new one. we have to go back further in time to find a very different kind of ocean; one where the bottoms had very little oxygen.

A ferry ride to Canadian territory.The black sea bottom beds show far more lamination and almost no fossils, the only remains are of surface-dwelling creatures of the time; Fish and chambered cephalopods such as nautiloids and ammonites. Layering was caused by the same sedimentary processes that were found in the younger Bainbridge Island Beds. But unlike beds deposited on a well-oxygenated sea bottom, here the bottom was devoid of oxygen. The numerous blebs of pyrite or fools gold, a sulfur-rich mineral formed in the absence of oxygen, the rock and fossil records offered testimony this unmixed or stratified Ocean was far more common over most of geological time. They're characterized by an oxygenated surface layer over a much thicker stratum with little or no oxygen. At the bottom, sediments are filled with black minerals colored by the abundance of sulfur similar on any beach as the clam digger gets below oxygenated sand and enters that thick black layer with its rotten egg smell.

So toxic were Canfield oceans that they may have reduced animal life, or even inhibited it's first evolution for millions of years during the long Precambrian era … the time from life's origin to less than 600 million years ago. There seem to be two reasons for this; first is the toxicity of the hydrogen sulfide but just as important the microbes' inhibition of nitrogen formation and compounds useful for plant life. While many kinds of microbes can fix biologically useless nitrogen an essential element for life into compounds are biologically useful, eukaryotes… plants, animals, fungi and other groups cannot do this and depend on microbes to do it for them. With sulfur bacteria little nitrogen becomes available and a nitrogen-poor ocean would be an ocean literally in need of fertilizer and not getting it, like soil from which all the nitrogen has been bleached. Only a small amount plant life will grow and a mass extinction will soon follow.

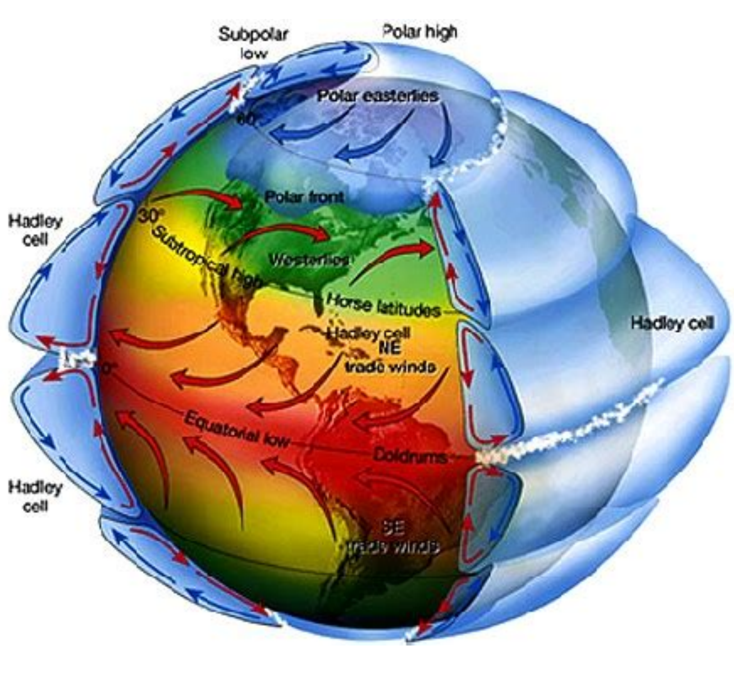
The P-T extinction was a time of the Canfield ocean. The Jurassic extinction biomarkers are also characteristic; the purple and green sulfur photo-synthesizing bacteria that live in seas shallow enough for light to penetrate. Three different ocean states, the mixed ocean, two kinds of unmixed oceans; the anoxic and Canfield. Here the conveyor systems may determine which will be present. And it may not be the presence of any of these oceans that causes distress to life but the change from one state to another.

The source of the mass extinction was a change in the location at which bottom worlds are formed. Near the end of the Paleocene epoch the source of earth's deep water shifted from the high latitudes to lower latitudes and the kind of water making it to the ocean bottoms was different as well. It changed from cold oxygenated water to warm water containing less oxygen. The result was the extinction of deepwater organisms because this event is linked to a changeover of the conveyor belt system. What about the Permian? It turns out that for that too a changed conveyor holds the smoking gun.

In 2005 climatologist Jeffrey Kiehl and Christine Shields of the Climate Change Research Section at the National Center for Atmospheric Research use the global circulation climate model to look at the Permian world. They wanted to know if Permian Ocean circulation patterns were disrupted at the time of the extinction. When they plugged in the known positions of the continents and inputted a warmed world as well, the remodeled Permian world showed the shift in the positions of the conveyor belt occurrence. They proposed that global warming caused the change in Ocean State.

The ocean currents seemed to be controlled by the amount of ice cover on earth and the nature of tropical warming or cooling. By the end of the Permian, Earth appears to have had no ice caps. It all melted away. The conveyor current changed it's starting and ending points. That shift may have been crucial to the mass death that followed.

It seems clear by the end of the Permian, ocean circulation changes. Deep ocean bottoms filled with great volumes of warm, oxygen-free water. The same thing that happened at the end of the Paleocene Epic, but at a vastly increased scale and with vastly more destructive results. The stage was set and needed but one more trigger; the short term but massive infusion of greenhouse gases into the atmosphere changed the oceans. Virtually every shallow water area became filled with warm water without oxygen and the deep water brought up poison.



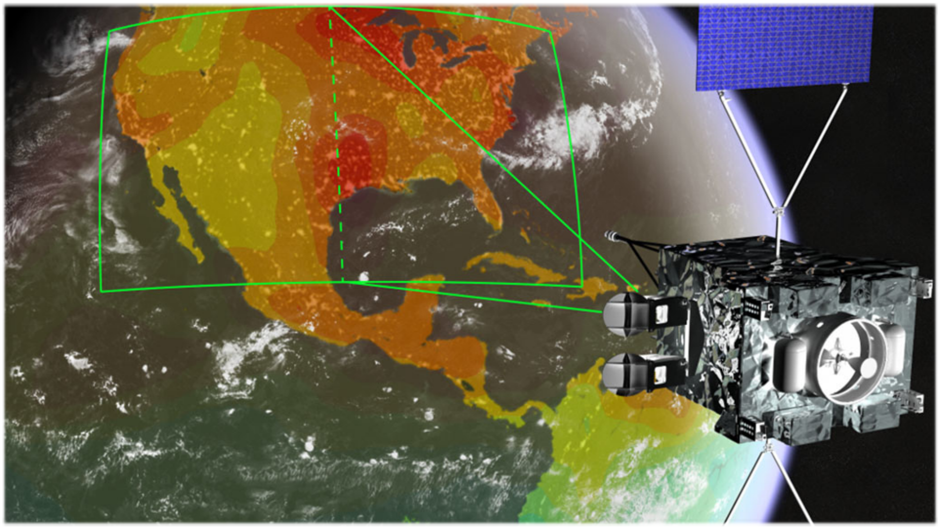
The 1997 book **Mass Extinctions and their Aftermath,** Anthony Hallam of the University of Birmingham and Paul Whitnall of the University of Leeds compiled data showings of the 14 mass extinctions, 12 of them were characterized by poorly oxygenated oceans. We now have a mechanism; perturbations or stoppage of the thermohaline conveyor current systems. It is time to stop looking at kill mechanisms; low oxygen, heat, perhaps excess hydrogen sulfide gas in water and air and start looking at the driver of these changes; the atmosphere itself.

The Driver of Extinction

Walvis Bay Namibia - Large rocks found in the seabed far offshore

Icebergs are floating rock collections. As glaciers move they scoop out rock, grind them round, freeze them into place. The embedded rock floats away in an iceberg. As they melt they drop their cobbles into the deep ocean…chilling evidence of Snowball Earth. On top of these, is a layer of rocks with evidence of bacteria, called stromatolytes, signs of a warming episode so intense it could have been carbon dioxide from volcanic activity.

The GEOCARB computer program shows precise carbon levels, evidence that the rapid warming also changed over the ocean from one state to another, from a static to a system of mixing currents, spreading oxygen throughout the world rapidly. Increases of just a few hundred parts per million causes the world



to heat radically. Equivalent drops will cool the planet. Because of the small amounts needed the climate can change very quickly… some changes in as as little decade. Geocarb calculates carbon dioxide and oxygen locals.

The carbon dioxide curve is striking compared with today. It was high for much of the Paleozoic era but oxygen begins to climb 375 million years ago. The levels of carbon dioxide plummeted and only rose again sometime into the Mesozoic era. Gas is plentiful, the maximum in the late Jurassic period, 150 million years ago and then declining to the Cenozoic era, coming to a minimum level today. But the last 200 years have produced an upswing of carbon dioxide too short duration to be visible on a long-term graph.

The long-term decline was due to the slow enlargement of the continents and to the increased amount of carbon locked up in vast mineral deposits which erode and liberate carbon at a slower rate than others are formed. Ultimately the long-term drop will spell doom for our Earth as a habitable planet but that is far in the future, and the reduction in atmosphere carbon dioxide has halted and reversed with a vengeance over not only the past centuries of the industrial age of humans but also dating back through the millennium that humans have engaged in agriculture.

When levels rise rapidly and coincide with mass extinctions the driver of extinction is the changes in the ancient conveyor belts caused by increases in greenhouse gases, the flood basalts that correspond with these extinctions are the source of the greenhouse gases. Fossil leaves measure ancient carbon dioxide levels. Plants are highly sensitive because atmospheric carbon dioxide is their source for carbon; a major building block of life. Tiny portals in our leaves are called Stomata. High levels of carbon dioxide produce a small number of stomata. With Low levels the opposite is true. This is readily observable in well preserved fossil leaves.

Greenhouse Extinctions

The world warms over short intervals because of the sudden increase in carbon dioxide and methane caused initially by formation of vast volcanic provinces called flood Basalts. Magma spreading over the plates, creating whole regions like India and South America. And releasing CO_2 gas.

A warmer world affects ocean circulation systems and disrupts the conveyor currents. Bottom waters have warm low oxygen waters dumped into them. The decrease of equator to pole temperature differences reduces ocean winds, surface currents to near standstill. Mixing oxygenated surface waters with increasing volume low oxygen bottom waters causes even shallower water to become anoxic. The bottom water is at depths where light can penetrate. The combination of low oxygen and light allows green sulfur bacteria to expand its numbers and fill the low oxygen shallows. They live with other bacteria that produces toxic amounts of hydrogen sulfide. This flux into the atmosphere is as much as 2000 times what it is today. The gas rises into the high atmosphere, breaks down the ozone layer. The increase in ultraviolet radiation kills much of the photosynthetic green plant phytoplankton. On its way up into the sky the hydrogen sulfide also kills plant and animal life and the combination of high heat, hydrogen sulfide creates a mass extinction… a Green House Extinction.

The conveyor disruption and processes;

Cambrian 490 million years ago

Late Ordovician 450 million years ago
Devonian– 360 million and 60 million years ago
Permian 253 to 247 million years ago
Triassic 205 to 199 million years ago
Toarcian 190 million years ago
Jurassic Cretaceous hundred and 44 million years ago
Cenomanian – Turonian 93 million years ago
Paleocene thermal 55 million years ago

All cause increased carbon dioxide in the atmosphere, leading to change in ocean currents, and eventual …anoxia.

"The event is called "Euxinia," It results from the proliferation of a kind of archaea which grow wild very quickly, when and where two conditions are met: low oxygen in the ocean, as in the "stratified ocean" and a supply of the nutrients that archaea use.

The Arctic ocean is near, perhaps within 10 years, of the critical temperature where, at the prevailing level of salinity, the northern "lungs of the planet" might stop.

This thermohaline current will cut off precisely when the temperature of minimum water density is reached at the surface. Hydrogen sulfide production in just the North Atlantic is already enough to produce the "eocene extinction', which was enough to kill off all mammals larger than a mouse, but not enough to kill off the mouse.

Professor Marty Hoffert of NYU, a leading oceanographer, shifts attention to the Antarctic currents, the more important of the "lungs of the planet." The Antarctic THC is the one large source of oxygen to the Pacific Ocean, and others."

I was startled to learn that THC has already shut down. Fresh water and water ice that should ring the Antarctic has already cut off this current, resulting in a steady drop in the thickness of the deep water containing oxygen which supplies the Pacific.

The thickness on the Pacific side is down to about 500 meters. It's much worse than the Atlantic, and is decreasing by 114 meters a decade. Clearly this calls for more sophisticated modeling, but it looks like we have 40 years left, more or less. Picture a man who is already underwater, whose lungs are not getting more oxygen, but has 40 years of oxygen left in those lungs.

In fact, the earth already experienced a cutoff of the southern THC, and stratified ocean, relatively recently – just 50,000 years ago. The study of Oxygen Minimum Zones offers many important clues. But what about the second trigger required for massive Hydrogen sulfide production in the Pacific – the supply of nutrients?

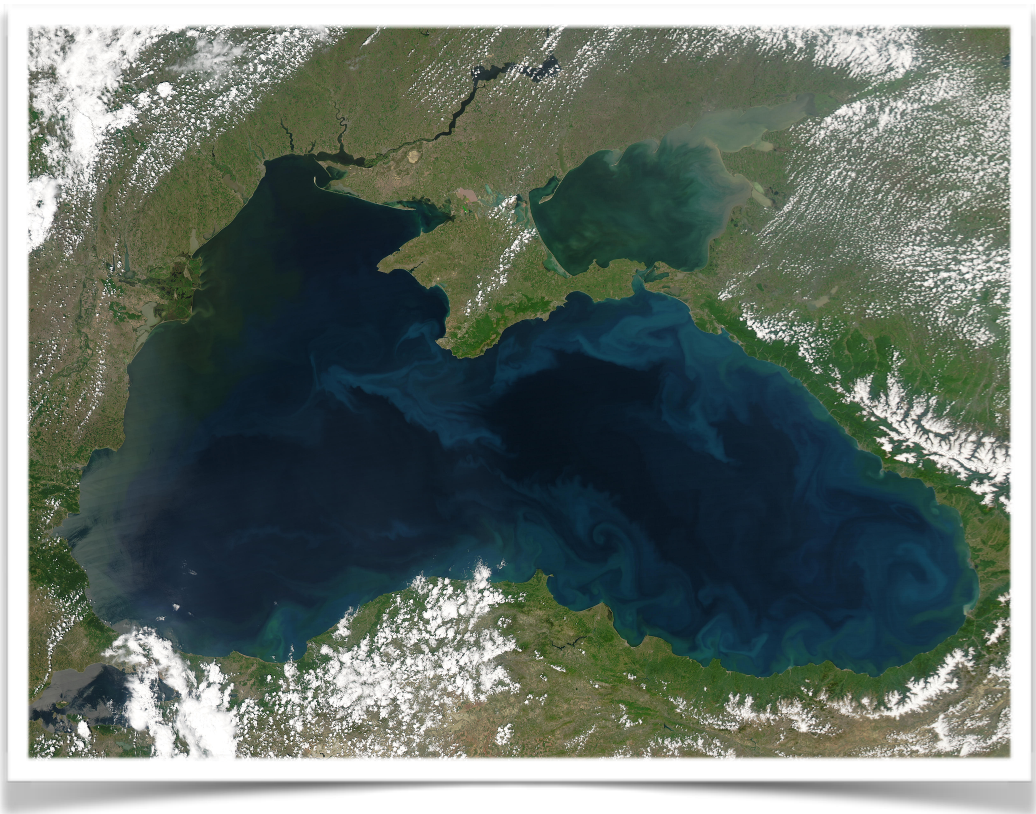
Unfortunately, the situation today is far riskier than it was in those years, because of another massive change which we humans have created – agricultural runoff. We have not yet seen really huge consequences from agricultural runoff pouring into the oceans because the high levels of oxygen were enough to prevent proliferation of archaea. But this runoff is truly massive by historical standards.

Humans now manage more than half the plant life of earth, and the productivity of that plant life has been doubled by a massive application of fertilizers, accompanied by an equally massive discharge into the oceans, unprecedented in history. Agriculture in China, California and Japan inserts huge runoffs into the Pacific. This needs to be studied in more detail, and perhaps there is even some hope of controlling it, but for now the best guess is that we are cooked.

Upwelling to release poison gasses from the ocean to the atmosphere might kill us all. The Black Sea already has become vast reservoir of Hydrogen sulfide poison, but, due to quiet seas, and low flows of wind, it has not yet led to outbreaks of mass death. Not yet.

Upwelling is substantial by northern Chile, Peru and Mexico, but also in California. Because the water is not as deep as in the Arctic, in areas like the Baltic, we may see these euxinia effects sooner. Hydrogen sulfide-producing archaea are probably active in areas with environmental problems, but when low oxygen hits most of the Pacific and the Arctic, things will immediately become very much worse.

Hydrogen sulfide is actually more poisonous than hydrogen cyanide, but from the historical literature it would take something like two thousand years to build to fatal levels. But even at much lower concentrations, the global effects would be severe.



Within a decade or two from the start of hydrogen sulfide upwelling, the world would smell so bad that reproductive behavior of most mammals would be severely curtailed, except for a few species like nasty rats which might be stimulated. Initially, Hydrogen sulfide would mostly break down to other gasses, causing acid rain and a new “ozone hole” leading to fatal radiation sooner than outright Hydrogen sulfide poisoning. Effects would appear sooner and faster in the upwelling zones.

All of this is a reasonable guess, but more research is needed to give us a more precise understanding of the range of uncertainties, and an understanding of what might help in reducing the probability of …human extinction. Renewable energy would not be enough by itself to save us, but it would be a help in increasing the possibility of survival. A greater, faster expansion of renewable electricity may be even more essential to other serious threats of extinction of the human species.

Robert Scribbler. [3]

A Modern Extinction Threat
Much Greater and Coming Much Sooner
Than Has Previously Been Suspected

The Extinction Threat is focused on the rise of CO_2 in the atmosphere. It is actually more complex than that. Current levels of C02 are about 350 Parts per million. Previous geologic eras have seen ten times that concentration. During the Jurassic Era dinosaurs were alive and levels were 3500 to 3600 hundred parts per million. The Earth's climate was much warmer, and tropical vegetation dominated the land areas of the Earth's surface. Increased volcanism injected Greenhouse gases into the atmosphere also during earlier eras and the Earth has large volcanic provinces in the Northwest US, the Deccan traps in India, and the Siberian Traps in Russia. There are also large igneous provinces under the ocean, and in the volcanic tectonic plates boundaries where there are today's subsea volcanic events.

New knowledge of deep climate history has provided a context for those skeptical of the changes in the Earth's anthropocene induced C02 increase and of the rationale to limit the fossil fuel infrastructure and economy and to question the recent conclusions of the InterGovernmental Panel on Climate Change of the United Nations.

Enormous amounts of money are at stake in the existing energy infrastructure. Those invested in oil, gas, and coal production have much to lose in questioning humanity's impact on the atmosphere… questioning the need to change quickly from fossil fuel production which overwhelmingly dominates the Earth's multi-trillion dollar energy economy. These economic interests dominate geo-politics, with pernicious "oil wars" and the struggle for more carbon fuels, with natural gas and fracking.

The "climate debate" has been fueled by a fossil fuel industry disinformation campaign about the science of CO_2 increases in the atmosphere, whether they are a by-product natural environment sources or really a function of the rapidly expanded global fossil fuel economy. This has avoided rational discussion of creating an energy revolution and what economic incentives and capital investments are needed. We must save hydrocarbon resources for non-fuel use, and change to clean energy needed for both growth in global demand and to mitigate the unquestionable environmental devastation that scientists have been warning us about.

The **Hydrogen Sulfide Extinction Threat** must move this debate to a global mobilization campaign for both survival and to include the construction of a space economy to acquire this enormous amount of energy.

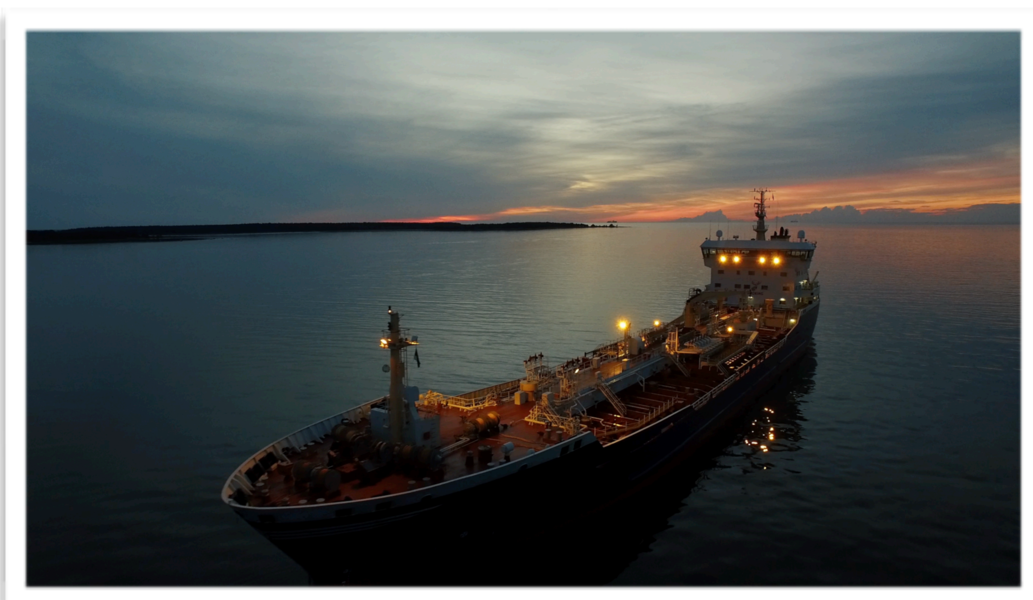
Besides CO_2 a variety of other greenhouse gases begin to play a greater role in climate change as warming shifts continue. As the Northern Hemisphere warms

3 Robert Scribbler

methane locked into the permafrost of Canada, the US, and Russia will be released. In the warming oceans there are reservoirs of methane hydrates as well. A warmer Earth increases water in the atmosphere, also a greenhouse gas. We can plot a correlation of ocean warming and the severe hurricanes of recent years. But another historical climate change phenomena has gone under the radar that involves ocean circulation and the flows of oxygen from the surface to the deep ocean.

We have increased our understanding of these shifts in relation to the Pleistocene glaciations and their association with the Earth's Milankovich orbital cycle, …the variations in eccentricity, axial tilt, and precession of the Earth's orbit... with changes in Earth's ice cover and albedo in reflecting sunlight back into space.

Most alarming Climate History, is when anoxic bacteria in the deep ocean multiply when oxygen is cut-off by interruptions of recirculating ocean currents. These anoxic bacteria increase and begin to dominate deep ocean ecology. They produce Hydrogen Sulfide; a gas more toxic than the cyanide used in Hitler's Holocaust.



In that spring a ship sails through the Baltic. Deep below, Dark Cthulu stirs…. single celled creatures grow, bubbles appear passing up through the mud. At the surface the bubbles pop, as the ship sails near. On the bridges, one sailor looks at the Officer. He makes a face. Something smells.,. In a moment the office turns to him ….Jesus!, a horrible stench… then the sailor coughs….

Below in the mates' cabin, others start to cough. One wakes, sits up, trying to get his breathe. He starts to choke….Others gasp and wake, grabbing their throats, trying to get their breath. Back up in the bridge, the officer and mate are on the floor, dead. The ship sails on, controlled by automatic cyber systems.

Lake Kivo, - Democratic Republic of the Congo

Two thousand times larger than Lake Nyos, this lake is also supersaturated. On the shore, the City of Goma; population two million. There are other danger zones. The bottom of the Black Sea is anoxic and lifeless because of trapped gases.

4 The Baltic
5 Off the Coast of Namibia
6 Off the Oregon Coast
7 In the Chesapeake Bay

Massive hydrogen sulfide releases can begin poisoning our atmosphere in as little as 40 years.

Eutrophication

The early humans found the land they roamed fertile. When they first settled in one place to grow crops they started to change the land. The first harvest in any field is bountiful. Food grains and other crops need carbon, oxygen and nitrogen. In the natural state, these elements are cycled through growth and decay and regrowth. When you remove the crops from the cycle, year after year, you deplete the fertility of the field. So the first crop from any field is bountiful, but year after year you deplete nitrogen. Nitrogen is absorbed by fungi in the roots of legumes; beans and similar plants. But this is a long, slow process. Taking food out of the land, you take the nitrogen, the energy…

the land becomes less fertile. People came to rotate their crops, planting legumes every few years, taking land out of production to let it regenerate…or, moving on…

Human and animal waste is rich in nitrogen. Spread into the fields, it increases fertility. In time, ancient repositories of guano or bird droppings, became worth more than gold. Wars were fought over guano. Even human waste was collected, licensed and controlled by the King. But there was only so much manure to help feed an expanding human population.

Then came a technological breakthrough. Two German scientists developed a mechanical method to fix nitrogen directly from plain air, to liquify it, and distribute it world-wide. Now, nitrogen could be injected directly jnto the fields. The harvest exploded, along with the population that fed on these foodstuffs… humans that demand ever more energy.

Now farmers all over the world inject nitrogen into the soil, along with pesticides and other chemicals. These seep into the aquifers, run off in the rains, flow into the streams and rivers and end in the sea. They maintain productive croplands, but also feed algae blooms that absorb oxygen from the oceans, creating dead zones, vast wastelands where no oxygen-breathing creatures can survive. Into these zones, which are as big as whole states, anerobic bacteria grow, grow like Chtuthu, and create hydrogen sulfide…poison.

Robert Scribbler

Awakening the Horrors of the Ancient Hothouse.

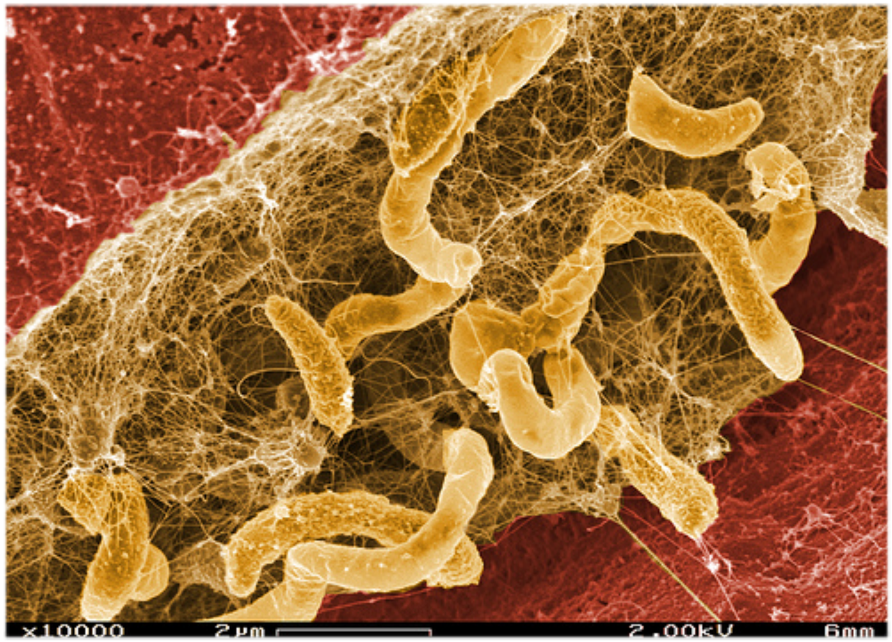
Human imagination is not without a sense of dramatic irony. Fiction sometimes possesses a broader perception of real world risks and their implications than the more defined warning signals coming from the sciences.

Cthulu is a metaphor for one of the worst of the world's ancient climate horrors — the oceanic production of hydrogen sulfide gas during hothouse events… a production implicated in many of the worst mass extinction events ever, of life on Earth.

Hydrogen Sulfide is a bi-product of bacterial metabolism in the Ancient Oceans. Understanding this ancient horror, we must look at some of the world's oldest and smallest creatures. Primordial bacteria.

Three and a half billion years ago, the Earth was a hot, toxic place, bombarded by solar radiation, still cooling after its formation. Oceans covered its surface, continents had yet to emerge. Atmospheric levels of CO2 were high, free oxygen was virtually nonexistent.

Microbial organisms thrived, including Desulfovibrio vulgaris, a hydrogen sulfide producing bacteria. Deprived of oxygen, the means of respiration for non-plant



organisms, the microbes, it required other sources for its simple cellular metabolism. Sulphate was common in the world's oceans and reacted well with hydrogen, which was also common. There emerged some of the oldest known living organisms — the sulphate reducing bacteria. These combine sulphate and hydrogen to produce hydrogen sulfide gas(H_2S). Ancient oceans were cauldrons bubbling over with hydrogen sulfide, the bi-product of these primordial organisms' respiration, in much the same way that oxygen is a bi-product of plant respiration and CO_2 is a bi-product of animal respiration.

Called a Canfield Ocean, after Donald Canfield's 1998 paper, this was the state until the emergence of more complex life two and a half billion years ago. By six hundred million years ago, the Canfield Ocean state only very rarely came into being and when it did, mass death followed.

Changes came with the emergence of oxygen. As the Earth system matured and new organisms developed, CO_2 reducing photosynthetic life emerged and began to produce an abundance of oxygen. Toxic to the ancient organisms, the abundance of oxygen pushed the sulphate reducing bacteria into the world's low oxygen corners. The deep ocean, or anaerobic mud became a haven for these tiny primordial monsters. Never again would they dominate. But, from time to time, when primordial ocean states would infrequently emerge during hot-house phases in Earth's climate progression, these life forms would explode, producing prodigious volumes of very toxic gas.

A volatile gas, hydrogen sulfide is deadly to most plant and animal life. It results in cardio-pulminary shock, then death. Lower levels cause loss of smell, blindness, respiratory infections, and loss of neurological and nervous system function. Human lethality begins around six hundred parts per million. Smaller mammals with higher respiration rates begin to die at around 450 ppm. Doses of 10-20 parts per million cause eye irritation. Doses between the irritation dose and the lethality dose over extended periods cause eye damage and degenerative nerve and lung changes.

In the environment, hydrogen sulfide gas reacts with hydroxyl and oxygen to produce sulfur dioxide. This draws down oxygen levels. Hydrogen sulfide is heavier than air, and pools at lower elevations, but is light enough to be born aloft by winds. At high enough concentrations, it seriously degrades the Earth's protective ozone layer. Geological records show such events occurring during the last 250 million years. During the Permian extinction event, fossils have been found with the characteristic UV damage that would with a degraded ozone layer.

At high enough concentrations, hydrogen sulfide burns. A 4.3 percent concentration is combustible, producing a lethal bluish flame. Natural gas can contain 90 percent hydrogen sulfide from the catalytic reaction of the hydrocarbon with minerals in the Earth. This is a constant danger to workers in the oil and gas industry. Risk of hydrogen sulfide release into the environment has greatly increased with widespread fracking by high pressure liquids to rupture tight gas deposits and chaotically release the substance at one of the US's one million well sites.

The volatility, danger, and toxicity of the gas… its lethality resulted in its use as a chemical weapon during World War I.

Culprit of Past Mass Extinctions

High concentrations of hydrogen sulfide in a Canfield ocean and large methane pulses from the sea bed during catastrophic warming events, have been implicated in numerous mass extinctions. The Permian-Triassic extinction, the Triassic-Jurassic, and the PETM extinction show signs of anoxia and hydrogen sulfide. Earlier Devonian and Ordovician extinctions were also likely caused by anoxia and hydrogen sulfide. Lesser extinctions in which ocean anoxia probably played a part include the Ireviken, Mulde, Lau, Toarcian and Cenomanian-Turonian. Hydrogen sulfide is a primary extinction mechanism in stratified, anoxic oceans.

In a Canfield Ocean world, large, episodic releases of hydrogen sulfide gas would cause local mass poisonings of land animals, especially those living near large bodies of water. The ocean itself would be brimming full and spilling over with this nasty substance, highly toxic to life, requiring extreme adaptation to survive.

Depletion of atmospheric oxygen through plant killing by hydrogen sulfide gas and its long-term reaction with oxygen would also make life far more difficult to terrestrial creatures. Massive amounts of sulfur dioxide would combine with the hydrogen sulfide pulsing into the atmosphere to create an ongoing, long-term degradation of the ozone layer, further harming surface dwelling plants and animals.

During the Permian Extinction, a global hothouse with a massive flood basalt, may have wiped out more than 70% of organisms… more than 95% of all life on Earth.

Expanding bottom anoxia, hypoxia and hydrogen sulfide production since 1960 in the bottom zone of the Baltic Sea. Red indicates region experiencing low or no oxygen content. Black indicates areas where Hydrogen sulfide gas is detected.

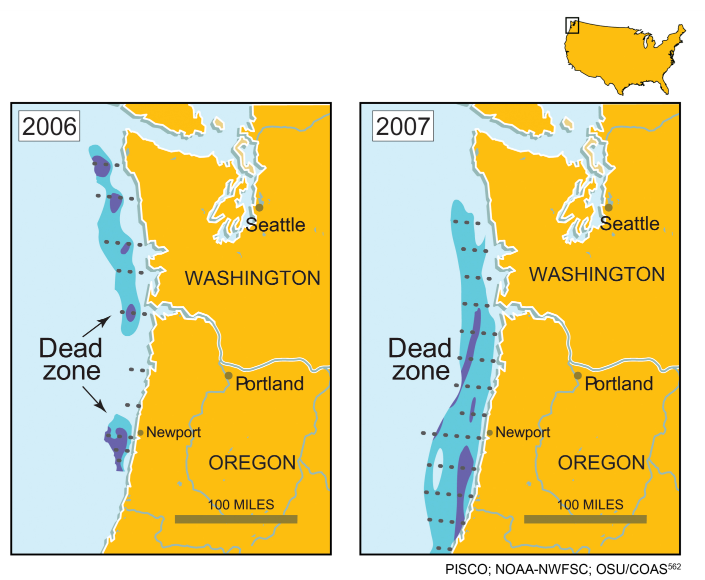
With warming the oceans are rapidly becoming more stratified and less oxygen-rich, mixing between various layers is beginning to shut down reducing oxygen content in the deeps and spurring the expansion of dead zones.

Over the past 150 years, the Pacific Ocean has become more stratified at a pace ten times that seen during the end of the last ice age twelve thousand years ago. Such a rapid pace of stratification is putting severe stress on the world's oceans with numerous regions showing hypoxia and becoming anoxic.

Very large dead zones have been observed in the Pacific off the coast of Oregon. Others occur at the mouth of major river systems, such as within the Gulf of Mexico, where the appearance of massive toxic algae blooms is now an almost annual event. Almost all ocean dead zones are expanding, leading to the dramatic reduction in habitat for numerous fish species. Research provides ample evidence that ocean hypoxia is expanding concurrently with a rapidly expanding ocean stratification. Off the coast of Namibia, in the Black Sea, in the Baltic Sea, in the Gulf of Mexico, in the Chesapeake Bay, and off the coast of Oregon, large and expanding zones of hydrogen sulfide have been observed in deep water environments. In some regions, this rises to the surface resulting in major fish kills and a rotten egg smell. The world's ocean system is suffering the heavy bombardment of a new mass extinction event.

Off the Oregon Coast,

…one of the world's largest and most oxygen-starved dead zones expands. The oxygen levels are so low that fisherman bring back horrific tales of baby bottom-dwelling crabs and octopus climbing anchor ropes to escape their oxygen-starved environment. Masses of starfish perished during 2013 and 2014. They turned to goo. The fact that this sci-fi-esque mass death occurred near one of the world's



Climate change affects coastal currents that moderate ocean temperatures and the productivity of ecosystems. As such, it is believed to be a factor in the low-oxygen "dead zone" that has appeared along the coast of Washington and Oregon in recent years.[561] In the maps above, blue indicates low-oxygen areas and purple shows areas that are the most severely oxygen depleted.

largest dead zones should not be lost. Volumes of hydrogen sulfide gas are high enough to cross the ocean-air boundary. The Oregon ocean system has strong up-welling currents that push bottom waters through stratified layers to the surface. If these oxygen-starved bottom waters contain hydrogen sulfide gas, as they increasingly do, this poison can be transported into the local atmosphere. Since the dead zone's discovery in 2001, its expansion has been both deeply concerning and well documented, showing a rapid, dangerous growth.

In **Namibia**, huge volumes of organic compounds are flushed down streams and rivers into the sea. They flow into the deep directly off Nambia's coasts. The bottom hosts both an anoxic environment and hydrogen sulfide producing bacteria. Hydrogen sulfide gas periodically erupts into the atmosphere.

The Very Real Threat. There are few limiters to oceanic hydrogen sulfide production in the world's increasingly stratified, oxygen-starved oceans. Sulphate is one of the most common elements. It is present in volumes greater than those seen during the Permian Extinction when these tiny monsters are thought to have done their worst.

Iron and manganese in the ocean aids boundary layers that keep a lid on hydrogen sulfide. But even in the anemic circulation of stratified and Canfield oceans, upwelling will bring greater volumes of the toxic gas closer to the surface, rendering metals that reinforce the boundary layer useless. Such metal concentrations currently prevent hydrogen sulfide from penetrating the surface layer in the Black and Baltic Seas and the Chesapeake Bay where modern industrial farming provides extra nutrients upon which these dangerous microbes feed.   As hypoxia and anoxia progress with human-caused warming and as glacial melt alters the ocean currents and mixing, hydrogen sulfide in the deep ocean will increase.

Dead Cthulu Rises. We are tiny, weak beings at the mercy of great natural forces which we can barely conceive or understand… forces that we have unwittingly, callously and ignorantly set into motion.

Long ago, when I was a child, I met an amazingly kind, adventurous and inquisitive man. He was a local paramour in ocean and bay research. He was in contact with the ocean and Chesapeake bays, venturing to explore and conduct research on marine life. He was the impetus behind marine science camps hosted by the Virginia Institutes of Marine Science, Norfolk Academy, and Old Dominion University. But this was later. Now, Rick was helping an elementary school student present on the issue of our then expanding understanding of marine science.

Living so close to the bay and ocean, I was intimately in contact with the living boundary of land and sea. I seldom had the opportunity to indulge my passion but at age 10 I was given the opportunity to give a broad marine science presentation for my classmates. As part of my project, I constructed models depicting the current state of world ocean research. I illustrated the various known zones of the bathysphere, the light and life filled ones and the more mysterious and far less well understood depths. But Rick was the centerpiece of my presentation. He was my keynote. And he energetically answered all my own and fellow students' questions, speaking in the kind and intriguing manner that would later draw so many into his charismatic orbit.

I observed an increasing concern about both the health of the Chesapeake Bay and the neighboring oceans. In later years, Rick's attitude, once so full of optimism, bordered on cynicism. The world he loved so deeply was experiencing death on a scale that horrified him. And he harbored a deep sense of betrayal that we weren't doing more to stop the slaughter of the living things both beautiful and wondrous.

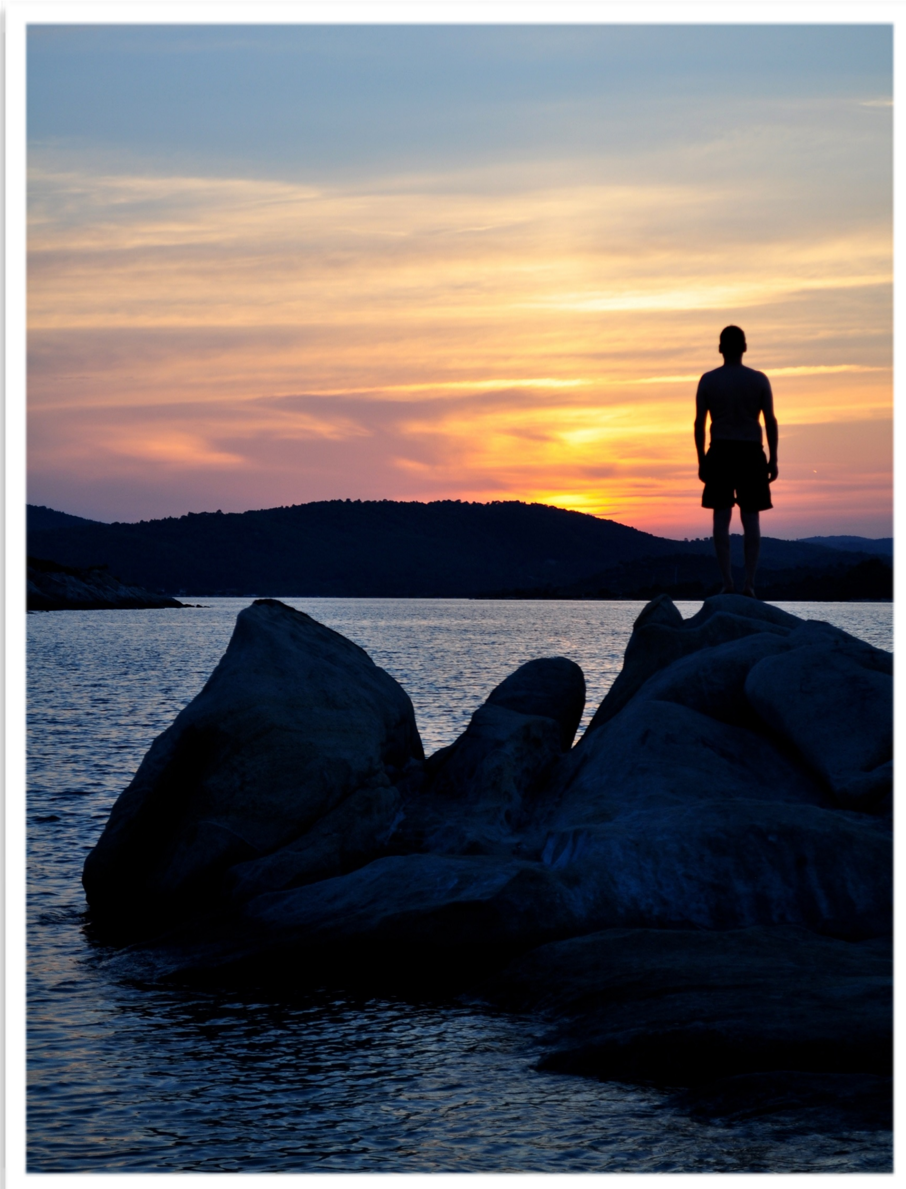
Rick committed suicide. One of the great ocean pioneers took his own life. And I couldn't help but wonder if the horrible commercialization and cheapening of all things he held most dear, along with their subsequent damage and the risk of terrible harm had robbed his life of beauty and purpose.

Rick was a very intelligent, sensitive man. He knew what was happening to the Bay and ocean on a personal level. When the Bay was harmed it hurt Rick too. He knew how temperature changes affected the depths. He was on the front line studying it. He was hauling up the fish and water samples. He measured with his own hands. Was the awakening of terrible Cthulu, in the form of hypoxia, anoxia and deadly hydrogen sulfide producing bacteria, too much for Rick to continue bearing witness? Did his pleas to those working in the marine science community fall only on deaf ears? Was it just too much for this sensitive, feeling, and intelligent man to bear?

Our lives and the life of the ocean are deeply connected. One cannot remain healthy without the other. The damage our industrial emission of greenhouse gasses is doing to the world ocean system is horrific.The damage we have done to those most sensitive creatures, for future decades and centuries, is tremendous. The ocean suffocates, bleeding deadly hydrogen sulfide gas. Cthulu rises from his ancient house in the depths. And yet we continue down the wretched path in pursuit of more terrible things to come.

So the un-sustainability of our Earth's current industrial civilization is producing a global extinction threat much faster than estimated. Some have argued that we have perhaps 100 years to turn back the climate effects that humanity is inducing. But now it seems the clock is running much faster and that there are no winners in this disaster scenario. There will be just losers or perhaps with an intense global effort a global multi-win survival campaign to escape a credible threat of modern massive extinction beginning in as little as 40 years.

In this threat we have met the enemy and he is us! All of us. All the major



industrial and economic competitive powers must swim or sink together. A Global Survival campaign must mobilize the industrial and economic resources of the nations to address this threat and a program of Sustainable Development Goals must also include addressing hope for global survival.

Humanity's future is already tied to the development and use of space-based resources and space-based energy which vastly exceed the resources available on the

Earth. We believe that the Development of the Space-based economy should be considered an 18th Sustainable Development Goal of the United Nations.

David Dunlop - October 2018[4]

Given the greater clarity in understanding the modern extinction threat, this transition to utilization of space based clean energy sources and material resources, which is within the collective grasp of humanity, is no longer a "nice option", it is critical to humanity's survival and the survival of the evolutionary heritage of terrestrial life.

If humanity is to survive it must become a sustainable space-faring civilization using the vast resources available to meet the requirements where our population is already exceeding the carrying capacity of our Earth and destroying the habitats that sustain the evolutionary heritage and creatures on which we are co-dependent. We must expand the Earth's Economy to include the volume of cislunar space including the surface of the Moon and Mars and also utilize asteroidal resources in this expanded economy. Our survival on Earth and survival as a space faring species are of one piece. We must marshal the support of all nations and in particular those with the industrial and financial resources to reshape a sustainable economic system with the financial and political mechanisms for a global survival campaign. Each country must align and optimize it's economy with this global campaign so that no nation is excluded.

The economic growth potential offers hope based on radical improvement in reducing humanity's footprint on the Earth through advanced design and engineering systems which can provide dramatic benefits for humanity and the environment. The addition of space based energy and material resources includes the investment in fusion technology.

The United Nations evolved from the victorious alliance over the Axis Powers and was intended to prevent another World War. The UN has achieved that goal and reduced the strategic threat of nuclear arms proliferation thus far but has not erased the competitive ambitions involved in a multi-polar economic world. Nothing like a Global Campaign for Survival mobilized by the Great Majority of Nations represented in the UN was envisioned at that time, but that must be achieved now as a new requirement for humanity's survival both on Earth and beyond the Earth. This challenge represents our collective species intelligence test one that we must not fail, and one where we work to succeed together as a species whose ultimate potential is as yet unrealized both on our home planet, within our home solar system…and beyond.

It is a footnote to our extinction that in 50,000 years of our development, in 10,000 years of history, that in only 25 years we developed both the Atomic weapons to wipe us from the earth and the means, space colonization, to survive; that, within a few hundred years, we developed technology to harness the great stored energy of our

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[4] David Dunlop

planet, to create the ability to reproduce ourselves to the point where our numbers alone, combined with that technology and pure blindness to the result has brought us to the brink of our own-caused extinction. The Petrie Dish.

EARTH

No wind, a hundred and twenty degrees Fahrenheit. Morning heat and no trees for shade. Vegetation is low, stunted, parched. The Life… scorpions, spiders, flies, burrows of small animals, slim, bipedal dinosaurs, scrawny and starving… the desert in his heat and aridity. No wind… hot barrenness.

But it is the sea itself that is most frightening. Waves slowly lap on the quiet shore; slow motion waves with the consistency of gelatin. In shallows, mountains of similar mats grow toward the sea's surface. They are stromatolites.

A mere flatness. An ocean without whitecaps. To the horizon, an unending purple color, a vast flat oily purple not looking like water not looking anything like our world. No fish break the surface, no birds or any other flying creatures swoop down looking for food. The purple color comes from vast concentrations off anerobic bacteria for the oceans have all become covered with the hundred foot veneer of purple and green bacterial soup.

Far from the fetid shore a large bubble of gas belches from the viscous oil slick. Carbon dioxide gas is not here nor even methane. This is hydrogen sulfide produced by green sulfur bacteria growing amid their purple cousins. Upward to the sky, vastly high overhead, thin clouds exist at an attitude far in excess to clouds found on our earth. Their existence changes the very color of the sky itself. We are under a pale green sky and the smell of death and poison.

This should make every citizen stand up. Dinosaurs are in the movies. Here's a process that is very real; mass extinction. Carbon dioxide is carbon dioxide. Whether it comes from a smoking volcano or a smoking car the question becomes…that when the rate of carbon dioxide increase in our world is on par with the rate during these times greenhouse extinctions occurred, how much danger are we in?

So what we know is that four and a half billion years ago the solar system was formed. If there was an intelligence at work it would have set up the simple rules of physics. Energy is matter. Matter Is energy. Energy reacts on matter. Gravity is opposed by centrifugal force. Small particles spin around each other in different configurations to form atoms. Atoms combine in different ways to form molecules. Complex molecules spark into life.

Our planet developed, through time, into different worlds. As it cooled, carbon dioxide was released, the gas warming the atmosphere of the planet.

Energy photons from the sun split it and let it recombine with hydrogen to form hydrocarbons; leading to organic life. Some of the early worlds were based on oxygen lifeforms, starting with single cell creatures and growing more complex. First plants and photosynthesis creating more plant matter, then animal forms with more mobility sped up the process.

During this time, catastrophes periodically reset the earth. We know of five great mass extinctions and many more minor ones. We know because we can read the surface history of the earth like a book. The pages …corresponding to eons, have buckled up on themselves as tectonic plates shifted, leaving cliffs; fracture zones where the layers of history can be seen.

At each geological era, we see ancient mass extinctions where life is wiped out only to start again on a different track, to become more complex. In the deepest and earliest layers we see simple creatures on a path of complexity interrupted again and again but eventually leading up to the dinosaurs.Each of these processes seem to happen over eon's; millions and millions of years.

We now propose that the dinosaur's extinction 65 million years ago was a quick one caused by a massive asteroid strike and the world-wide fires, smoke and dust leading to years long winters and a subsequent ice age. But some of these extinctions' stages took much longer to develop as the earth overheated; often times by volcanism and the spread of flood basalts that formed large areas of the surface of the earth while releasing hot-house gasses.

We also have evidence of greater changes in the world; those times when oxygen was supplanted by another common element; sulfur. These sulfur-based worlds could not support oxygen based life; could not support life more complex than the lower forms. The super dramatic shifts caused by long-term climate heating that ended the oxygen-carrying currents in the oceans permitted the rise of hydrogen sulfide gas, and a completely flipped chemistry of the planet surface.

All of these things took place over an extremely long amount of time. And the H2S world, sometimes called a Canfield Ocean, perhaps less capable of developing complex life, again devolved to oxygen. But its surviving life forms, aerobic bacteria, still reside in the dead zones of the deep ocean. And they still represent a existential threat to oxygen-oxygen-based life. …   the Tipping Point.

The dinosaurs we're reptiles; a form of life that takes much of its heat and energy directly from the sun. These cold blooded creatures could not support the energy drain of a highly developed brain. Dinosaurs with plenty of time to evolve, never evolved enough to create the means of establishing asteroid defense.

Today, with the latest iteration, this system-of-systems is trying to learn, trying to develop a complexity to achieve stasis, if that is the goal of the universe …Is it the goal to create creatures who can manage the planet, who can maintain a balance, and so, survive….so that life can escape this single planet and spread to other worlds…other parts of the universe? Are we the Cosmic Experiment?

Only in the last iteration has the highest intelligence in the biosphere so cleverly manipulated that biosphere that they have, in a few hundred years, rather than eons, brought about their own mass extinction… the death of all of them and every other oxygen-breathing creature on the planet… through the limitations of reason and emotion…through stupidity. Proving perhaps this iteration of life, as many iterations before it, has not been capable of developing intelligence quickly enough to survive toward whatever destiny there finally is… If that is the case, then we deserve our coming extinction. We are an experiment that didn't work out.

Charles Proser, Dr. Peter Ward, Robert Scribbler, Dre. Paul Werbos, Dr. Martin Hoffert, David Dunlop

Paul J. Werbos is a scientist known for his 1974 Harvard University Ph.D. thesis, which first described the process of training artificial neural networks through backpropagation of errors.He also was a pioneer of recurrent neural networks. He served as program director in the National Science Foundation.

Peter Douglas Ward (born 1949) is an American paleontologist and professor at the University of Washington, Seattle, and Sprigg Institute of Geobiology at the University of Adelaide. He has written numerous popular science works for a general audience and is also an adviser to the Microbes Mind Forum.

Robert Scribbler is a progressive novelist, non-fiction writer and emerging threats expert. He served in the combat arms, spent 3 years as a police officer, and 3 years as Editor, Emerging Threats for Jane's Information Group. He's spoken at over 250 events nationwide and is currently working to both complete his third speculative fiction novel "The Death of Winter" and my second non-fic -- a climate justice based book called "Abolition -- Ending the Resource Curse," and a climate/emerging threats book entitled "The Second Great Dying."

David Dunlop (1946-2018) was a writer and Board Member of the National Space Society and Chairman of the International NSS Committee to the United Nations, IPCC.

Charles Proser is an Emmy Award-winning director cameraman, a screenwriter and producer.

PART 3

What is to be done immediately…

A world-wide Marshall Plan, a Manhattan Project… A New Green Deal

Project Drawdown https://www.drawdown.org

A Plan to draw down and sequester carbon. An infrastructure, a new structure to save the world… What we can do…what we have to do now…

A natural change of 100ppm normally takes 5,000 to 20,000 years. The recent increase of 100ppm has taken just 120 years. Human CO_2 emissions upset the natural balance of the carbon cycle. Man-made CO_2 in the atmosphere has increased by a third since the pre-industrial era, creating an artificial forcing of global temperatures that warm the planet.

While fossil-fuel derived CO_2 is a very small component of the global carbon cycle, the extra CO_2 is cumulative because the natural carbon exchange cannot absorb all the additional CO_2.

#1

“Every refrigerator and air conditioner contains chemical refrigerants that absorb and release heat to enable chilling. Refrigerants, specifically CFCs and HCFCs, were once culprits in depleting the ozone layer. Thanks to the 1987 Montreal Protocol, they have been phased out. HFCs, the primary replacement, spare the ozone layer, but have 1,000 to 9,000 times greater capacity to warm the atmosphere than carbon dioxide.

IMPACT: *emissions reductions can be achieved through the management and destruction of refrigerants already in circulation. Over thirty years, containing 87 percent of refrigerants likely to be released could avoid emissions equivalent to 89.7 gigatons of carbon dioxide. Phasing out HFCs per the Kigali accord could avoid additional emissions equivalent to 25 to 78 gigatons of carbon dioxide. The operational costs of refrigerant leak avoidance and destruction are high, resulting in a projected net cost of $903 billion by 2050.*

#2

Wind energy is at the crest of initiatives to address global warming in the coming three decades. Today, 314,000 wind turbines supply nearly 4 percent of global electricity, and it will soon be much more. In 2015, a record 63 gigawatts of wind power were installed around the world.

RESULTS BY 2050 - 84.6 GIGATONS REDUCED CO_2
$1.23 TRILLION -NET IMPLEMENTATION COST
$7.43 TRILLION - NET OPERATIONAL SAVINGS

IMPACT: *An increase in onshore wind from 3 to 4 percent of world electricity use to 21.6 percent by 2050 could reduce emissions by 84.6 gigatons of carbon dioxide. At a cost of $1.23 trillion, wind turbines can deliver net savings of $7.4 trillion over three decades of operation. These are conservative estimates, however. Costs are falling annually and new technological improvements are already being installed, increasing capacity to generate more electricity at the same or lower cost.*

#3

A third of the food raised or prepared does not make it from farm or factory to fork. Producing uneaten food squanders a whole host of resources—seeds, water, energy, land, fertilizer, hours of labor, financial capital—and generates greenhouse gases at every stage—including methane when organic matter lands in the global rubbish bin. The food we waste is responsible for roughly 8 percent of global emissions.
RESULTS BY 2050 -70.53 GIGATONS REDUCED CO2
GLOBAL COST AND SAVINGS DATA TOO VARIABLE TO BE DETERMINED
IMPACT: *After taking into account the adoption of plant-rich diets, if 50 percent of food waste is reduced by 2050, avoided emissions could be equal to 26.2 gigatons of carbon dioxide. Reducing waste also avoids the deforestation for additional farmland, preventing 44.4 gigatons of additional emissions. We used forecasts of regional waste estimated from farm to household. This data shows that up to 35 percent of food in high-income economies is thrown out by consumers; in low-income economies, however, relatively little is wasted at the household level.*

Shifting to a diet rich in plants is a demand-side solution to global warming that runs counter to the meat-centric Western diet on the rise globally. That diet comes with a steep climate price tag: one-fifth of global emissions. If cattle were their own nation, they would be the world's third-largest emitter of greenhouse gases.

#4

RESULTS BY 2050
66.11 GIGATONS
REDUCED CO2
GLOBAL COST AND SAVINGS DATA TOO VARIABLE TO BE DETERMINED
IMPACT: *Using country-level data from the Food and Agriculture Organization of the United Nations, we estimate the growth in global food consumption by 2050, assuming that lower-income countries will consume more food overall and higher quantities of meat as economies grow. If 50 percent of the world's population restricts their diet to a healthy 2,500 calories per day and reduces meat consumption overall, we estimate at least 26.7 gigatons of emissions could be avoided from dietary change alone. If avoided deforestation from land use change is included, an additional 39.3 gigatons of emissions could be avoided, making healthy, plant-rich diets one of the most impactful solutions at a total of 66 gigatons reduced.*

In recent decades, tropical forests have suffered extensive clearing, fragmentation, degradation, and depletion of biodiversity. Once blanketing 12 percent of the world's landmass, they now cover just 5 percent. While destruction continues in many places, tropical forest restoration is growing and may sequester as much as six gigatons of carbon dioxide per year.

#5

RESULTS BY 2050
61.23 GIGATONS
REDUCED CO2
GLOBAL COST AND SAVINGS DATA TOO VARIABLE TO BE DETERMINED
IMPACT: *In theory, 751 million acres of degraded land in the tropics could be restored to continuous, intact forest. Using current and estimated commitments from the Bonn Challenge and New York Declaration on Forests, our model assumes that restoration could occur on 435 million acres. Through natural regrowth, committed land could sequester 1.4 tons of carbon dioxide per acre annually, for a total of 61.2 gigatons of carbon dioxide by 2050. Only carbon stored in soil organic matter and aboveground biomass is accounted for; below-ground biomass is not included*

Education lays a foundation for vibrant lives for girls and women, their families, and their communities. It also is one of the most powerful levers available for avoiding emissions by curbing population growth. Women with more years of education have fewer and healthier children, and actively manage their reproductive health.
Educated girls realize higher wages and greater upward mobility, contributing to economic growth. Their rates of maternal mortality drop, as do mortality rates of their babies. They are less likely to marry as children or against their will. They have lower incidence of HIV/AIDS and malaria. Their agricultural plots are more productive and their families better nourished.
Education also shores up resilience and equips girls and women to face the impacts of climate change. They can be more effective stewards of food, soil, trees, and water, even as nature's cycles change. They have greater capacity to cope with shocks from natural disasters and extreme weather events.
Today, there are economic, cultural, and safety-related barriers that impede 62 million girls around the world from realizing their right to education. Key strategies to change that include:

- make school affordable;
- help girls overcome health barriers;
- reduce the time and distance to get to school; and
- make schools more girl-friendly.

- # #6

RANK AND RESULTS BY 2050
51.48 GIGATONS
REDUCED CO2
SEE IMPACT BELOW

IMPACT: *Two solutions influence family size and global population: educating girls and family planning. Because the exact dynamic between these solutions is impossible to determine, our models allocate 50 percent of the total potential impact to each. We assume that these impacts result from thirteen years of schooling, including primary through secondary education. According to the United Nations Educational, Scientific, and Cultural Organization, by closing an annual financing gap of $39 billion, universal education in low- and lower-middle-income countries can be achieved. It could result in 51.48 gigatons of emissions reduced by 2050. The return on that investment is incalculable.*

#72

In ancient Amazonia, the waste disposal method of choice was to bury and burn. Wastes were baked beneath a layer of soil. This process, known as pyrolysis, produced a charcoal soil amendment rich in carbon. The result was *terra preta*, literally “black earth” in Portuguese. Today, *terra preta* soils cover up to 10 percent of the Amazon basin, retaining extraordinary amounts of carbon.

These ancient roots of what is now called biochar have modern promise for agriculture and the atmosphere. Biochar is commonly made from waste material ranging from peanut shells to rice straw to wood scraps. During the slow baking of biomass in the near or total absence of oxygen, gas and oil separate from carbon-rich solids. The output is twofold: fuels that can be used for energy and biochar that can be used to enrich soil.

When biomass decomposes on the earth’s surface, carbon and methane escape into the atmosphere. Biochar retains most of the carbon present in biomass feedstock and buries it. Rendered stable, that carbon can be held for centuries in the soil—a much-delayed return to the atmosphere. Theoretically, experts argue, biochar could sequester billions of tons of carbon dioxide every year.

0.81 GIGATONS REDUCED CO2
GLOBAL COST AND SAVINGS DATA TOO VARIABLE TO BE DETERMINED

Rank	Solution	Sector	TOTAL ATMOSPHERIC CO2-EQ REDUCTION (GT)	NET COST (BILLIONS US $)	SAVINGS (BILLIONS US $)

1	**Refrigerant Management**	Materials	89.74	N/A	-$902.77
2	**Wind Turbines (Onshore)**	Electricity Generation	84.60	$1,225.37	$7,425.00
3	**Reduced Food Waste**	Food	70.53	N/A	N/A
4	**Plant-Rich Diet**	Food	66.11	N/A	N/A
5	**Tropical Forests**	Land Use	61.23	N/A	N/A
6	**Educating Girls**	Women and Girls	51.48	N/A	N/A
7	**Family Planning**	Women and Girls	51.48	N/A	N/A
8	**Solar Farms**	Electricity Generation	36.90	-$80.60	$5,023.84
9	**Silvopasture**	Food	31.19	$41.59	$699.37
10	**Rooftop Solar**	Electricity Generation	24.60	$453.14	$3,457.63
11	**Regenerative Agriculture**	Food	23.15	$57.22	$1,928.10
12	**Temperate Forests**	Land Use	22.61	N/A	N/A
13	**Peatlands**	Land Use	21.57	N/A	N/A
14	**Tropical Staple Trees**	Food	20.19	$120.07	$626.97
15	**Afforestation**	Land Use	18.06	$29.44	$392.33

16	Conservation Agriculture	Food	17.35	$37.53	$2,119.07
17	Tree Intercropping	Food	17.20	$146.99	$22.10
18	Geothermal	Electricity Generation	16.60	-$155.48	$1,024.34
19	Managed Grazing	Food	16.34	$50.48	$735.27
20	Nuclear	Electricity Generation	16.09	$0.88	$1,713.40
21	Clean Cookstoves	Food	15.81	$72.16	$166.28
22	Wind Turbines (Offshore)	Electricity Generation	14.10	$545.30	$762.50
23	Farmland Restoration	Food	14.08	$72.24	$1,342.47
24	Improved Rice Cultivation	Food	11.34	N/A	$519.06
25	Concentrated Solar	Electricity Generation	10.90	$1,319.70	$413.85
26	Electric Vehicles	Transport	10.80	$14,148.00	$9,726.40
27	District Heating	Buildings and Cities	9.38	$457.10	$3,543.50
28	Multistrata Agroforestry	Food	9.28	$26.76	$709.75

29	Wave and Tidal	Electricity Generation	9.20	$411.84	-$1,004.70
30	Methane Digesters (Large)	Electricity Generation	8.40	$201.41	$148.83
31	Insulation	Buildings and Cities	8.27	$3,655.92	$2,513.33
32	Ships	Transport	7.87	$915.93	$424.38
33	LED Lighting (Household)	Buildings and Cities	7.81	$323.52	$1,729.54
34	Biomass	Electricity Generation	7.50	$402.31	$519.35
35	Bamboo	Land Use	7.22	$23.79	$264.80
36	Alternative Cement	Materials	6.69	-$273.90	N/A
37	Mass Transit	Transport	6.57	N/A	$2,379.73
38	Forest Protection	Land Use	6.20	N/A	N/A
39	Indigenous Peoples’ Land Management	Land Use	6.19	N/A	N/A
40	Trucks	Transport	6.18	$543.54	$2,781.63
41	Solar Water	Electricity Generation	6.08	$2.99	$773.65
42	Heat Pumps	Buildings and Cities	5.20	$118.71	$1,546.66

43	**Airplanes**	Transport	5.05	$662.42	$3,187.80
44	**LED Lighting (Commercial)**	Buildings and Cities	5.04	-$205.05	$1,089.63
45	**Building Automation**	Buildings and Cities	4.62	$68.12	$880.55
46	**Water Saving - Home**	Materials	4.61	$72.44	$1,800.12
47	**Bioplastic**	Materials	4.30	$19.15	N/A
48	**In-Stream Hydro**	Electricity Generation	4.00	$202.53	$568.36
49	**Cars**	Transport	4.00	-$598.69	$1,761.72
50	**Cogeneration**	Electricity Generation	3.97	$279.25	$566.93
51	**Perennial Biomass**	Land Use	3.33	$77.94	$541.89
52	**Coastal Wetlands**	Land Use	3.19	N/A	N/A
53	**System of Rice Intensification**	Food	3.13	N/A	$677.83
54	**Walkable Cities**	Buildings and Cities	2.92	N/A	$3,278.24
55	**Household Recycling**	Materials	2.77	$366.92	$71.13
56	**Industrial Recycling**	Materials	2.77	$366.92	$71.13
57	**Smart Thermostats**	Buildings and Cities	2.62	$74.16	$640.10

58	Landfill Methane	Buildings and Cities	2.50	-$1.82	$67.57
59	Bike Infrastructure	Buildings and Cities	2.31	-$2,026.97	$400.47
60	Composting	Food	2.28	-$63.72	-$60.82
61	Smart Glass	Buildings and Cities	2.19	$932.30	$325.10
62	Women Smallholders	Women and Girls	2.06	N/A	$87.60
63	Telepresence	Transport	1.99	$127.72	$1,310.59
64	Methane Digesters (Small)	Electricity Generation	1.90	$15.50	$13.90
65	Nutrient Management	Food	1.81	N/A	$102.32
66	High-speed Rail	Transport	1.52	$1,038.42	$368.10
67	Farmland Irrigation	Food	1.33	$216.16	$429.67
68	Waste-to-Energy	Electricity Generation	1.10	$36.00	$19.82
69	Electric Bikes	Transport	0.96	$106.75	$226.07
70	Recycled Paper	Materials	0.90	$573.48	N/A
71	Water Distribution	Buildings and Cities	0.87	$137.37	$903.11
72	Biochar	Food	0.81	N/A	N/A

73	**Green Roofs**	Buildings and Cities	0.77	$1,393.29	$988.46
74	**Trains**	Transport	0.52	$808.64	$313.86
75	**Ridesharing**	Transport	0.32	N/A	$185.56
76	**Micro Wind**	Electricity Generation	0.20	$36.12	$19.90
77	**Energy Storage (Distributed)**	Electricity Generation	N/A	N/A	N/A
77	**Energy Storage (Utilities)**	Electricity Generation	N/A	N/A	N/A
77	**Grid Flexibility**	Electricity Generation	N/A	N/A	N/A
78	**Microgrids**	Electricity Generation	N/A	N/A	N/A
79	**Net Zero Buildings**	Buildings and Cities	N/A	N/A	N/A
80	**Retrofitting**	Buildings and Cities	N/A	N/A	N/A