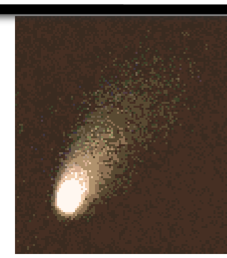

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Dinosaur Extinction: *One More Hypothesis*

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Abstract: Attention is called to the great destruction that resulted from a meteorite impact in Siberia in 1908. A larger impact would cause more widespread destruction. Several larger impacts may have occurred in geologic time. The survivals and extinctions at the close of the Cretaceous are such as might be expected to result from intensely hot winds such as would be generated by extra large meteoritic or planetesimal impacts. It is suggested that, when the various hypotheses as to dinosaur extinction are being considered, this one be added to the others.

Many large and previously flourishing animals became extinct at the close of the Cretaceous. The date of their passing may have been a matter of thousands of years, but no fossil evidence clearly proves this idea; the time might have been much more brief. No proof exists as to what caused these extinctions; we have only the opinions or guesses of various paleontologists. Several bits of evidence do exist, however, and may be reconsidered. These clues point toward one explanation which has seldom been noticed and never emphasized, but which deserves notice along with the others.

The literature on plant fossils indicates that a drastic change in the world's vegetation occurred between the Jurassic and the Cretaceous, but not at the Laramide Revolution (the end of the mesozoic). Angiosperms were certainly extremely rare before the Cretaceous, but during that period they increased with explosive rapidity, and assigned the dominant position in the world's landscape that they now occupy. The Raritan (Cretaceous) formation of New Jersey contains over 200 species of fossil Angiosperms, about 70 percent of all the plant species that occur there. In the succeeding Magothy fora (still Cretaceous) the modern type plants are equally dominant with (for example) oaks, sassafras, tulip trees, sedges, and grasses.

The Cretaceous grasses warrant emphasis. These plants, seemingly humble, are the world's best fodder for large animals. In zoos, the large mammals are appropriately called the "hay stock." The great herds of American bison lived in grassland. The huge African animals, such as zebra, rhinoceros and eland, are inhabitants of the grassy plains or veldt; grass is their necessary nourishment.

The Dakota flora, also of Cretaceous antiquity, is very interesting, comprising several hundred species, 90 percent of which are flowering plants. This quite modern-type vegetation occurred through Minnesota, Iowa, Nebraska and Kansas, where Bison recently Flourished, and where the large Cretaceous animals similarly nourished.

There is no evidence of a radical change in the world's vegetation at the time of or since the Laramide Revolution. The Eocene reveals plant life continuing in much the same pattern as before the "revolution." The animals that prospered on that vegetation for millions of years in the Cretaceous should have continued into the Tertiary), but many did not. Which ones did not? Why did some survive?

There is no evidence of a radical change in the under-water life of the earth coincident with the Laramide Revolution, although many large cephalopods died out. This is to say that the completely aquatic faunas of the Paleocene do not differ markedly from those of the late Cretaceous. Thus a study of the fossils of most invertebrate and fish groups does not offer clues as to the nature of the post-Cretaceous reptilian catastrophe.

Non-aquatic invertebrates are, and long have been, chiefly hexapod in nature. The paleontologic record of insects is too irregular, too often broken, to help with the present problem. Non-aquatic vertebrates, however, do afford some extremely interesting data.

The Chelonia had been present since at least the Triassic, about as common as they are today.

The Sauropterygia were represented in the Cretaceous only by the plesiosaurs, which had turtle-like bodies and long snakelike necks. Their obvious ancestry goes back to the Triassic. The Ichthyosarlria were even more beautifully adapted to fish-catching, but they appear to have become extinct early in the Cretaceous. Large plesiosaurs may also have vanished prior to late Cretaceous, although this is not certain.

The Rhynchocephalia must have existed through the Cretaceous because one species (Sphenodon) still lives in New Zealand. This primitive type goes back at least to the Triassic, and is represented by at least one species in the Jurassic, but by no Cretaceous or Tertiary fossils. It is much like the earliest (Carboniferous) reptiles.

The Crocodilia, new in the Jurassic, continued through the Cretaceous, survived its close, and have become more common in the Cenozoic.

The Pterosauria, new in the Jurassic, flourished through that period and until the end of the Cretaceous, when they became extinct.

If one regards the Dinosauria as a single order, there were seven reptilian orders in the Cretaceous, but there were eight if one separates the Dinosauria, as is probably better, into two orders. The Saurischia appeared in the Triassic, and were large and numerous through the Jurassic, reaching a climax of size and abundance late in the Cretaceous. The Ornithischia did not certainly evolve until the Jurassic, but were extremely common and big animals until the Laramide Revolution.

The Squamata, new in the Jurassic, became more common in the Cretaceous, and have increased further in the Cenozoic. In the late Cretaceous we find common large aquatic lizards called mosasaurs, a few iguanid lizards similar to the modern Sauromalus, a few anguinomorphs like the Recent "slow worms" and gila monster, some Platymota (monitors) and a few, newly evolved Serpentes. Some of these. were burrowing forms, others resembled Recent boas.

Aves appeared in the Jurassic, but, perhaps because out-flown by pterosaurs, they remained uncommon throughout the rest of the Mesozoic. Only since the reptilian competition has been reduced have birds greatly flourished. This they have indeed done through the whole Cenozoic to date. They waxed rapidly in importance early in the Tertiary.

The first certain Mammalia are Cretaceous in age, although several Jurassic fossils are probably of this class, and some Triassic Ictidosauria, certainly at least intermediate, may already have produced milk for their young. It is clear that Cretaceous mammals were uncommon and small. The outstanding type as one that differed little from the modern opossum. With the advent of the Tertiary, mammals suddenly increased greatly in size and abundance, filling niches left vacant by the extensive reptilian extinctions.

It seems to me that one should find some explanation of the events in analysis of what perished and what survived.

Of the dinosaur extinction, A. S. Romer says it ". . . is one of the most dramatic events in vertebrate history." Many hypotheses have been advanced to account for the observed facts. Not one of them has been proven; all are speculative, quite as much as the present one.

In 1937, while reading and discussing the above-described paleontologic events, an additional explanation occurred to me; that is to say, one more theory as to what may have caused the change in fauna at the close of the Cretaceous. Many to whom I have suggested this explanation point out objections, and quite properly. In all fairness it should be kept in mind, however, that grave objections are also offered against all the other opinions or hypotheses.

I suggest an event, or series of events, of brief heat, of temperatures high enough to kill exposed large animals in certain parts of the world.

My suggestion has been criticized because it presumably did not account for the lack of change in flora at the end of the Cretaceous, and by another critic who argued that it did not account for the great change in flora at that time. As noted above, the evidence favors a Cretaceous vegetation much like that of the present. Romer suggests that lack of proper food plants caused the extinctions, but does not belabor the point. Modern type vegetation is today more nourishing than the gymnosperms and pteridophytes which dominated the Jurassic, represented now by New Zealand would probably survive. Many plants live as roots while destroyed above ground, and sprout again. Others survive catastrophes as seeds although their mature plants perish. The events that I postulate would selectively favor Arctic and sub-Arctic vegetation, and many Cretaceous plants that survived the Tertiary are such as now flourish in the cooler regions, or on islands.

A common suggestion or opinion is that egg-eating enemies brought about extinction of the large reptiles. Why should egg-eaters select those and spare the eggs of birds, lizards and turtles! Were dinosaur eggs larger than ostrich eggs, or Apteryx eggs? Flightless birds characterized the Cretaceous as much or more than now, and many egg-eaters can climb or fly. This theory may be correct, but is completely speculative.

Some experts suggest that the large reptiles perished because of pituitary abnormalities. They certainly had large pituitary glands, but they were so supplied for literally millions of years, probably more than a hundred million years. A million years ago man's ancestors were still apelike. The large reptiles had been obviously healthy and prosperous for this vast length of time, with over-sized pituitaries all that while. Why then should they all perish so nearly simultaneously, from such a well tolerated gland?

One opinion has it that the whole world became lethally cold, or a cold age that lasted comparatively long in geologic terms.

This would certainly have killed the dinosaurs. This theory has the great merit of accounting for the preferential survival of birds and mammals. They have such effective insulatory body covering (feathers and fur) that they can be, and are, homoisothermous. They endure cold now, and surely endured it in the Cretaceous, too.

World-wide cold would be more nearly complete in action than whatever-it-was that really happened. Palm trees survived, for example, and snakes and some lizards. Most significant, the geologist does not find any stratigraphic evidence of such a great ice age. The coldest epochs of the Pleistocene never froze the whole world; this theory is surely open to question.

Another hypothesis calls for a time of world-wide high temperature, again lasting comparatively long geologically speaking. This doubtless implies a gradual rather than instantaneous origin, and fairly slow recovery. It is quite certain that warmer than usual climates affect the continents from time to time. Tropical climate has prevailed in what is now north temperate region, probably several different times. One may suppose a hotter and hotter planet, even with equatorial regions too warm for animal life. But in this case, the dinosaurs would merely have migrated poleward. If our planet became hot enough to kill dinosaurs north of latitude 70, not much of anything would have survived anywhere. Sustained heat could have finally produced revolutionary changes even in the ocean. There is no stratigraphic record of such omnipresent lethal heat.

There is, however, logical reason to believe that heat was the doom of the dinosaurs; not long continued, but brief. Air temperatures may have been near boiling in the tropics, and up to 50&#176C. as far from the equator as latitude 50, but not with regular boundaries. Rather the fierce gales of heated air swirled here and there, missing some scattered small areas. Furthermore, where there was much snow to be melted. this melting cooled them to sub-lethal temperatures. Life went on in the sub Arctic.

It would require many centuries to warm up the ocean; even the very surface heats slowly, and the warmer water will stay on top, only sinking after a long, poleward journey. in fact, it cools notably before sinking. Hence the world's water changed little.

Let us see how the hypothesis of brief heat accords with the record of survivals and extinctions, why it might be preferred to other opinions.

As for vegetation--most mature vegetation would probably burn, but many roots survive, many seeds survive, and much snow-bound northern (and extreme southern) vegetation would survive even as mature plants. The trees and shrubs on mid-oceanic islands would be spared. When such an island is now denuded, for example, by a volcano, the rapidity with which it is reclothed in vegetation reveals that a nearly denuded world would be again green with plant life in a few thousand years.

than thaw them awake. Chelonia did survive.

The air-breathing plesiosaurs perished, although this may have been in the mid-Cretaceous.

The Rhynchocephalia survived, and demonstrate how a small animal, not large like a plesiosaur, may hold its own in an isolated, out-of-the-way area, which New Zealand is. Furthermore, Sphenodon spends much time in crevices or burrows.

Crocodiles survived, perhaps on the same basis as the turtles. Conceivably, it might have been only one batch of eggs, well buried in mud, that lived through a catastrophe.

The pterosaurs could not hide; they all perished.

All the dinosaurs perished.

Many of the Squamata lived through, as follows: Lizards of the Sauromalus type survived. These today are noteworthy for their tendency to crawl back into cracks and fissures. Several aguinomorph lizards survived; they also are fossorial or crytophilous. Some monitors survived; today they are found chiefly on oceanic islands--perhaps they had a similar placement in the Cretaceous. The Serpentes survived preferentially, but as already mentioned, some were burrowing forms. The others were of the boa type, which, even today, hides amazingly. I have searched for them in the tropics. They were found, but always in my experience, hiding in a hollow tree. They lie in wait for the victim, now generally a mammal. This victim, perhaps an opossum, crawls into the cavity vainly seeking asylum from its other enemies, only to become a dinner for the snake. This doubtless happened to Cretaceous opossums, too. These lizards and snakes have such ecological placement and habits that they are exactly the ones that might be expected to live through a fiery tempest.

The birds and mammals survived best of all. The Cenozoic is their period; these two classes have dominated the land since the earliest Tertiary time. They can live in the snow-covered high latitudes. Undoubtedly they lived there in Cretaceous times as well as now. Even boiling hot air, blowing over miles of snow, would cool down to a breathable degree.

I believe that objective, unprejudiced contemplation will find considerable plausibility in the present hypothesis.

A wholly reasonable and proper question of course arises; what could have caused brief heat, such as has been postulated?

An historical event occurred, and reading its description caused me to consider the present hypothesis.

At eight o'clock in the morning of June 30, 1908, a shower of meteorites struck near Vanovara, Siberia; these are the so-called Tunguska or Podkamennayn meteorites. Effects were noticed that same day in the records of the barograph at Kew Observatory in England, some 5,000 kilometers away, and the following evening a peculiar sky-glow was noted in England.

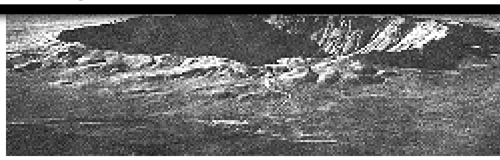
Study of the site was later conducted (1928) by a party of Russian scientists, led by L. Kulik. His reports, and others, are summarized in a chapter of H. H. Nininger's book about meteorites, entitled "Our Stone-Pelted Planet." The fiery mass was seen coming from the northeast, and the terrific explosion was heard by the inhabitants of the cities of Yenisseisk, Krasnojarsk, Kansk, Nijneudinsk and Kirensk. An earthquake was felt as far away as Irkutsk.

At the point of impact there are numerous craters 50 to 200 meters in diameter, but now nearly filled with water, vegetation and debris. The region is extremely wet and swampy.

In a circle of 20 kilometers diameter, the trees still stood, although scorched and carbonized by intense heat. Here the shockwave struck nearly vertically.

Around this, to a diameter of about 60 kilometers, the trees were prostrate as well as carbonized, tops directly away from the center of impact, flattened by the terrific wind. An area of nearly a thousand square kilometers had been heated so that all animal life perished. This included several families of human settlers, at least 1,500 reindeer, and numberless smaller animals. This is one of the most sparsely inhabited regions on earth, or the human deaths would have been far greater and worldwide attention demanded.

A representative eyewitness report is that of a farmer named Semenov, who lived 80 kilometers from the point of impact. He saw the blinding blaze of light and almost at the same instant felt a heat so great that he thought



damage (crater size) of those that caused the crater at Winslow, Arizona, some 5,000 rears ago, or the even larger Chubb crater in northeastern Canada. Other geologically recent meteoritic craters do not show, because of falls in the ocean (four-fifths of the earth's surface) or where vigorous erosion has obliterated them, as in the tropics.

One may profitably consider the Tunguska meteorite. It is only necessary to postulate a larger event of exactly the same kind, to implement the present hypothesis.

H. C. Urey has written authoritatively and interestingly on the history of the moon. He and others have shown that in the early time of our solar system the earth and moon were the targets of colossal bombardments. Some scientists assume that this bombardment ceased in the remote Pre-Cambrian, except for trivially small meteorites.

In late October 1937 the asteroid "Hermes" passed so close to the earth that even some astronomers envisaged the possibility of collision. It missed our planet by only some 480,000 miles, which is about the diameter of the moon's orbit, and only a little more than half the sun's diameter. Should we assume that never before in all the earth's history did any other asteroid come closer?

In view of the near approach of "Hermes," and the evidence of Chubb crater and Winslow, it would not be at all astonishing to discover that there have been three or four collisions of planetesimal size on our planet since the Cambrian--perhaps one every two or three hundred million years.

Heat of impact is amazingly effective. It has been discovered, for example, that battleship projectiles melt their way through several inches of steel armour as a result of the terrific heat energy of their slowing down. The energy of travel is converted to heat energy by the cessation of travel.

Meteorites that are slowed down by passage through the atmosphere become incandescent, and their outer surfaces not only melt, but even boil. Even stone and nickel-iron vaporize--the latter at about 2,500° C. Study of the surfaces of available meteorites amply confirms this.

The larger the meteorite (the greater its momentum) the less it is slowed down by passage through air. Small ones settle like drifting dust. Medium sized ones hit like cannon balls. One that was hundreds of meters in diameter might retain nearly its full interplanetary speed.

Kulik estimated the speed of impact of the Vanovara meteorite as well over 50 kilometers per second. Similar speeds for newly arriving meteorites are recorded by Nininger, La Paz, Stocking and others. Much slower speeds are measured for the ordinary meteorite that has been slowed down to incandescence and is available for easy measurement.

There is sound reason to expect that no extra large meteorite will ever be found anywhere, under any conditions. By "large" I imply units over a hundred meters in diameter. None are found, for example, at Vanovara, or at Chubb Crater, and none so large at Winslow. One's first assumption is likely to be that they are merely deeply buried, but another explanation is available.

Let us assume impact at the speed of only 10 kilometers per second, and cessation of motion within a depth or penetration of one kilometer. Iron at high temperatures has a specific heat of about 0.15, therefore the temperature generated by stopping would be

$$\frac{10^{12}\ cm^2/sec^2}{2 \times 0.15 \times \frac{cal}{gm.\&\#176C.}} \times \frac{4.18 \times 10^7\ ergs}{cal}$$

or a temperature of 6,666 degrees, which is more than twice the boiling point of iron. Assuming that half goes outward and half goes inward, the entire projectile would still vaporize.

Let us assume a meteorite of 100 meters diameter. its kinetic energy would be $MV^2/2$, its mass $3X10^7$ tons or $3X10^{13}$ grams. The total calories possible from the conversion of this kinetic energy into heat energy would be 1.5×10^{25}, Or enough to boil 10^{16} tons of water. In the entire ocean, there are only some 10^{18} tons of water.

almost incomprehensible figure.

An impact at only 1 kilometer per second would still yield $1.5X10^{25}$ calories, enough to boil 10^{14} tons of water. Assuming that to boil iron requires ten times the calories required to boil the same mass of water, this heat would still vaporize 10^{13} tons of iron, whereas the meteorite mass was $3X10^{7}$.

A meteorite so large as 100 meters diameter would instantly heat the vicinity of its impact; a region about twice its diameter, to vaporization, a much larger area to incandescence, more than a thousand kilometers diameter to the boiling point of water, and the whole world notably but briefly.

The size of the crater does not reveal the size of the individual unit. For example, Winslow Crater may have been made by a cluster or shower of separate meteorites, each small enough to be considerably slowed by the atmosphere. On the other hand, one or more of the units may have been so large as to vaporize, even there.

When iron vaporizes and cools, it precipitates in the form of minute spheres. Exactly such spheres are found around the Winslow Crater.

The Vanovara meteorite was certainly lethal to a diameter of 60 kilometers. The much larger Winslow meteorite was probably lethal for a diameter of 600 kilometers. One much smaller than the asteroid "Hermes" would be deadly for thousands of kilometers--a lethal belt actually circling the equator more than once. If it happened today, the human survivors might be only a few Eskimos, but they would re-people the earth in a few centuries. As on Krakatoa, they would find vegetation springing up from seeds and roots; there would be interesting survivors from Kerguelen and some mines in Siberia.

In my short lifetime we have witnessed the astronomically close approach of the planetesimal "Hermes." There is every reason to believe that in the remote past others had orbits that brought them even closer to ours. A few such may have existed and then ceased by final involvement with the earth's gravitational field, a spiral approach, and collision.

In a similarly short time the world has been struck by a meteoritic cluster that devastated a large area in Siberia. If this area had been in the United States, American scientists would have been impressed. They would not regard danger from impact as being preposterous, an assumption which is now common.

It is not fantastic to consider the likelihood that an extra large impact affected this planet some sixty million years ago. No human being was here to see it, or study it with radar. But just such extinctions occurred, and just such survivals occurred, at the end of the Cretaceous, as would be expected to occur as the result of impact from a planetesimal or an extra large shower of meteorites.

May we not take this into consideration as possibly having been the doom of the dinosaurs?

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Dinosaur illustrations are from digital images of the "Giants of the Gobi" exhibit at the Oregon Museum of Science and Industry, (**OMSI**), in Portland, Oregon by **R.D. "Gus" Frederick**. The Hale-Bopp comet image was also taken by Frederick in April of 1997 on KodaColor II 100 ASA. 10 seconds at f2.8. 130mm Lens and Minolta 35mm. The Winslow/Barringer crater image is from the cover of the book "The Meteor Craters" by Willy Ley. Copyright 1968. Published by Weybright & Talley: NYC

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