Was there, or was there not a meteoritic impact at the K/T boundary 65 million years ago?

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It was a so-called mass extinction. Two larger mass-extinctions are recognised: one at the Permo-Triassic boundary 250 million years ago and one 65 million years ago. The earlier extinction marks the boundary between the Palaeozoic (old life) and the Mesozoic (middle life), and the second lies between the Mesozoic and the Cainozoic periods. The K/T boundary event caused the disappearance of around 70 % of all species, while the P/T boundary event caused the disappearance of around 90 % of known species. All other so-called mass extinctions are dubious but the P/T and K/T are not (though we may discuss the numbers).

The K/T boundary: Who disappeared? The planktonic foraminfera. Some coccoliths disappeared permanently, while others only disappeared temporarily (the so-called 'Lazarus effect'). The ammonites and the belemnites disappeared permanently. Some lamellibranchs and gastropods too, while others made it across the boundary.

Common to all that disappeared is the possession of a planktonic carbonate larval shell. The larger animals in the marine ecosystem (such as the marine lizards (Mosasaurs) disappeared when the food chain broke down, because the primary produces were hit. The dinoflagellates were un-hurt and the same applies to the diatoms (siliceous algae). These two groups are without carbonate and they do not seem to be effected. It looks as though marine animals and plants using carbonate, spending their lives in the uppermost part of the water column (the photic zone) were effected.

At the K/T boundary, one observes the presence of a negative carbon isotopic anomaly. This is a drop in ^{13}C relative to ^{12}C. There are three carbon isotopes in our system: ^{12}C, ^{13}C, and ^{14}C. The last one is radioactive, disappears after some 60,000 years, and is without interest in our discussion. The ratio between the two others is usually recorded as a ‰ deviation relative to a standard.

The $^{13}C/^{12}C$ can be measured in carbonate or in organic carbon such as soot, charcoal or sporo-pollenine. The negative ^{13}C anomaly at the K/T boundary has been linked to a meteoritic impact, which was supposed to have caused darkness on earth for an extended period of time (months to years) and thereby killed the marine plants such as coccoliths. The coccolithophoriids produce carbonate plates that fall to the seafloor. These plates are slightly enriched in the lighter carbon isotope (^{12}C). Therefore, if they were stopped in their activity, there would be more ^{12}C left in the system causing a depression in the relative amount of ^{13}C. This must take place right at the disappearance time of the algae or very shortly after they were hit.

Registration of the carbon-isotopes from dinocyst skeletons at the K/T boundary in Denmark demonstrates that there is a time difference in the appearance of the isotopic deviation between Stevns Klint in the south-eastern part to Nye Kløv in the north-western part of the country. This time difference can be estimated to be around 100,000 years. At Stevns Klint, the boundary between the Cretaceous and the Tertiary deposits takes place at the so-called Fish-Clay horizon where carbonate producers such as coccoliths and foraminifera disappear suddenly. At Nye Kløv, the plankton continues 15 cm higher than the negative isotopic excursion! Stevns Klint represents a much shallower depositional environment than the one at Nye Kløv. It follows that the carbonate deposition ended earlier in shallow water than in deeper water.

In the 1950's Worsley proposed a hypothesis which would explain the clay or marl-layer found everywhere in the marine deposits at the K/T boundary (at Stevns Klint, the Fish-Clay). Worsley claimed that there was disorder in the global carbonate cycle and that the clay/marl was a dissolution residue. He suggested a general rise in the CCD (carbonate compensation depth) as the cause. This can be directly discarded, since a slow rise in the CCD would lead to longer hiati in deeper waters than in shallow water. If the rise were fast, it would lead to hiati of equal duration. We do, however, see that the shallow locality has a longer hiatus than the deeper one, and this is impossible in Worsley's theory.

Dinoflagellate resting cysts are made of sporo-pollenine (as are spores and pollen) which is extremely resistant. They can be oxidised whereby they disappear. Investigation of the dinocysts of the Fish Clay at Stevns Klint shows that the flora is dominated by a dinocyst, which does not occur at all in the underlying chalk. If the Fish Clay should be a dissolution residue, its content should originate from the chalk. Thus, the Fish Clay is a sediment deposited in Fish Clay time, and it is not a dissolution residue.

This allows us to continue with the argument. We may now make statements as to the cause leading to a stop in carbonate production initially in shallow water and later in deeper water.

The uppermost part of the oceanic column's primary production occurs through planktonic algae (coccolithophosiids, diatoms and dinoflagellates) that need light for their production. This part of the ocean is up to a maximum of 100m deep (generally less). It is in this part of the ocean that the planktonic larvae of carbonate-shelled organisms lived (namely, where the high production is found).

We are looking for a mechanism, which will selectively strike the carbonate-shelled organisms living in the uppermost part of the oceanic water-column. The present atmosphere has a CO_2 content of around 370ppm. One may ask how much CO_2 is needed in the atmosphere in order to make the top of the ocean acidic! The ocean is a very sluggish system and any mechanism that involves diffusion is much too slow to give an effect. However, the ocean has a so-called mixed-layer, i.e. the layer being mixed through wave action causing mechanical stirring. It extends to about 50m depth, which is the deepest wave-base.

At an atmospheric CO_2 concentration of 5500ppm, the pH (acidity) of the seawater is 7.0 at 20°C. The normal acidity of seawater is alkaline (at around 8.2) and laboratory experiments show that coccoliths have serious problems producing carbonate scales at a pH of 7.5. Coccolithophores can survive pH down to 5.5 but they stop producing plates. When brought back to normal conditions they start producing again (the 'Lazarus effect' *op. cit.*).

Cretaceous coccolith species found above the K/T boundary in Israel were primarily interpreted as re-deposited fossils. However, carbon-isotopic measurements showed that their composition was different from that of the Cretaceous fossils and that they gave an Early Paleocene signal. Thus, they had survived and were not re-deposited.

Our present CO_2 content in the atmosphere is rather low. We are at present in an interglacial period. In order to obtain a mass-extinction in the ocean it is necessary to increase the present CO_2 content by around five times. We do not need a pH in the top ocean of 7,0 since the primary producers only need a collapse value of around 7,5. This corresponds to around 1750 ppm CO_2 relative to the present 370 ppm). Is such an addition realistic?

We know one mechanism that releases huge amounts of CO_2 to the atmosphere. These are the so-called plateau-basalts (or continental flood basalts) that occur now and then in the history of the earth. At the K/T boundary the Deccan Traps basalt province was active and caused extrusion of an estimated 1,5 million km^3.

The two main gases, which are released by basaltic eruptions, are CO_2 and SO_2. There is 2-3 times as much CO_2 as SO_2. The isotopic composition of the volcanic CO_2 is around -23, and therefore much more negative than our present atmospheric CO_2 which is around - 7. 100 years ago it was only -6 but has changed through our burning of fossil fuel! We have found that degassing from $2,8*10^5$ km^3 basalt is sufficient. Thus, we are able to create a mass extinction among calcareous marine organisms that live in the upper photic zone by intensive volcanism.

The immediate effect of the volcanism would appear to be a strong greenhouse effect. However, the greenhouse is delayed because of SO_2 (which is oxidised in the atmosphere to SO_3 and forms micro drops of sulphuric acid). As the droplets are smaller than the wavelength of light, photons that enter a drop will have the same chance of being returned to space as travelling to the earth. We thereby have a greenhouse that is initially cold. The effect of the cooling is the formation of glaciers on the more elevated areas (mountainous glaciation) and Antarctica. This leads to drop in the sea level, which can be seen in the presence of hard-grounds at Stevns Klint. The first hard-ground is found 700,000 years before the K/T boundary. The second is in the Fish Clay and the third and largest is straight after the deposition of the *Cerithium* Limestone at Stevns. In terms of time, the last hard-ground occurs only 40,000 years after that in the Fish Clay. The magnitude of the regressions (sea level drops) can be monitored in the incised river valleys in USA.

A small explanation is needed: The ice started melting after the last glaciation 11,500 years ago. 5,000 years ago the sea level was higher than today. Thus in 6,500 years the sea level rose by 100m! If one studies a seismic profile across the lower Mississippi River one can observe that the real riverbed is at 90m depth below surface. When sea level was lower during glacial times the river carved out its bed so that it corresponded to the existing sea level.

700,000 years before the K/T boundary incised river valleys with a cutting depth of 8.5 to 10.5m are observed everywhere in the terrestrial deposits in North America. The distance from the riverbeds to the ocean at that time was from 300 to 500km. The slope was small (1 foot per mile) since the sediments were very soft. The first drop in sea level was by around 20m; the second (during Fish Clay time) around 30m and the last one around 50m. In order to have some basis for comparison: Melting the Greenland inland ice would lead to an increase in sea level of around 12m. Where the main bulk of the ice was at that time is not hard to guess, since Antarctica was lying over the South Pole as it is today. The effects of mountain glaciation can be observed in the Alps, where we find melt water sediments in the valleys as the only sign of the presence of the glaciers.

Each of the repeated cooling events is followed by a CO_2 greenhouse, which rapidly melts the ice, fills up the ocean and stems the groundwater. The riverbeds are filled by sediments and are commonly covered by a coal layer. The system with incised valleys and super positioned coal layers continues into the Tertiary, but has not been studied in detail yet.

Plants with C3 photosynthesis were the only plants in existence prior to Miocene time around 30 million years ago. Thus, C4 plants (grass, maize etc.) had not evolved yet. Dinosaurs were not grass-eaters for very good reasons!

When C3 plants assimilate CO_2 from the atmosphere they fractionate the carbon through diffusion processes so that cellulose from a pine tree will have a delta ^{13}C ‰ of -27. This means that they fractionate the atmospheric carbon with -20 delta values. Therefore we have a means to determine the atmospheric CO_2 isotopic composition in former time. When changes occur in the atmospheric isotopic composition, C3 plants the world over will register this in their cellulose. Through the study of plant carbon isotopes from closely spaced samples across the mass extinction boundaries we find a variation pattern that can be used to correlate the different localities in time, since the atmospheric system rapidly mixes. We find that there are a series of negative anomalies both before and after the K/T and the P/T boundary.

They cannot all be caused by extinctions. How many times can one become extinct? We are looking for a repeated cause and the only one available seems to be volcanism. Volcanic activity is characterised by high activity phases followed by calm time intervals. At the K/T boundary we may therefore take the isotopic variation as an indication of the activity of the Deccan Traps volcanism which repeatedly extruded large amounts of negative carbon into the atmosphere and which the plants faithfully incorporate into their cellulose (because they just could not help it).

The Deccan Traps volcanism starts with an intensive phase 700,000 years before the extinction of marine organisms. It is registered on Stevns Klint by a hard-ground. The hard-ground separates the white chalk from the overlying grey chalk. The grey chalk owes its colour to a raised amount of elementary carbon. This carbon has an isotopic composition of -26 to -27 while charcoal from the Fish Clay has a value of -25.

It has been suggested that a meteoritic impact caused worldwide forest fires at the K/T boundary. If this should be the reason for the elementary carbon (soot) in the grey chalk, we face a problem, because the meteorite should have arrived 700,000 years before the boundary. Soot from wood fires consists of non-combusted material and should have the same isotopic composition as the wood (charcoal). Part of the carbon in the grey chalk may stem from marine plants but also from the Boudouard reaction, which is active at volcanic eruptions. It leads to the formation of elementary carbon of very negative isotopic composition. The reaction calls for the splitting of CO into CO_2 and elementary carbon. It takes place at one atmosphere and in the temperature interval between 600 and 1000°C. Since there are no differences in the organic content between the white chalk and the grey chalk the main part of the elementary carbon must stem from volcanism. The carbon particles consist of fluffy aggregates with a grain size of around 0.2 microns.

In 1979, a meeting was held in Copenhagen and was concerned with the subdivision of the Cretaceous time period. At this meeting, some Americans presented an investigation of the trace-element chemistry of the K/T boundary layer from Gubbio, Italy. This layer corresponds to the Fish Clay at Stevns Klint. It is an old suggestion that the extinction at the K/T boundary could have been caused by a nearby supernova explosion followed by a particle radiation reaching the earth. Heavy elements are created in supernova explosions and therefore they had looked for presence of plutonium. The plutonium half-life is long enough to ensure its presence in 65 million years. They found no plutonium, and therefore: exit supernova!

They also looked for the element iridium (which is from the group of noble metals). Iridium was used because it is relatively easy to analyse by instrumental neutron activation (INAA). This had earlier been used to estimate the input of material from space into the deep-sea sediments. Meteoritic dust has a rather high content of iridium relative to the earth's crustal rocks. The amount of iridium was therefore expected to yield an estimate of the time it had taken to deposit the boundary clay. They found surprisingly high values and when analysing the Fish Clay from Stevns Klint they found even more. This made them suggest that the iridium could stem from a meteoritic impact. By simple calculation, the size of the heavenly stone could be estimated to 10-15 km in diameter.

Well, it was not geologists who suggested this, because they would have smelled a rat. When a meteorite approaches the earth it does so with speeds of 20 to 30 km/second. The energy from an impact of a 10-15 km body corresponds to earthquakes measuring around 15 on the Richter Scale. The consequence would be that all loose, shallow water sediments would be mechanically disturbed and all these sediments outside river mouths would travel to the deep sea as turbidites. However, we see no disturbances in shallow water sediments and the K/T boundaries in the deep sea are very calm and undisturbed. In short: there was no meteoritic impact!

The iridium enrichment was, however, still unexplained, but in 1983, iridium enrichment was found on flying dust from the Kilauea volcano on Hawaii. Later, recent emanation of Ir from the Reunion Island volcano was reported. Russian geologists collected volcanic ash from Kamchatka and found that the smaller the grain size and the further away from the volcano they spread, the more Ir was present. Hawaii and Reunion are both 'hot spot' volcanoes, but Kamchatka is calc-alkaline so there are wide possibilities for Ir production by volcanoes. This was, however, not known in 1979.

The Deccan Traps volcanic field in India stems from the passage of the Indian plate over the hot spot volcano on Reunion Island. At that time India was positioned around 30 degrees south. Since we today find emanation from the volcano corresponding to a concentration in the magma of 7 ppb Ir, it would be logical to look for Ir-bearing basalt in Deccan. French and Indian scientists have looked, but have not found any. The problem has been that they have been looking randomly, because they have been unable to determine the K/T boundary position in the terrestrial Indian deposits. It has recently been shown that a basaltic flow very shortly before the K/T boundary is Ir bearing.

Now let us look at the Ir anomaly as a unique phenomenon. Is it unique and does it occur everywhere at the same time? This would be expected if it should stem from an impact. We have to separate terrestrial and marine deposits in this context. In the marine realm, many places have preserved Ir enrichment at the K/T boundary coincident with the extinction level. This is however, not the case in the Negev, Israel, where there is none at the extinction level but it occurs later at the P1b-P1c plankton boundary. Four Ir enrichments have been reported from marine deposits of Upper Paleocene age from Slovenia. At El Kef in Tunisia, two enrichment levels were reported long ago, one is at the extinction level and the other is younger.

In the terrestrial deposits in North America, from Alberta, Canada to New Mexico in southern USA, an Ir enrichment has been found. It occurs in a coal layer, which can be placed time wise 40,000 years later than the K/T boundary, which is marked by a change in spores and pollen. It is found in the close vicinity of a rhyolitic ash layer and is unrelated to the marine enrichment. It is related to the volcanic ash layer. The same is the case with three Ir-anomalies in a lake deposit in NW India (Gujarat Province). The age of the latter is several 100,000 years earlier than the K/T boundary and all three are associated with rhyolitic ash layers.

The find of an Ir-bearing basaltic flow in India suggests the possibility that the Ir from the basalt eruption can be the source of the Ir enrichment in the ocean. The basalt flow in India is a single and not a composite flow with a thickness of more than 30m covering a large area. If the basalt should yield enough iridium to cause a general enrichment of 4 ppb (nanogram/gram) corresponding to $50 ng/cm^2$ we need $2,5*10^8$ kg of iridium. If we assume a degassing of 7 ppb (like the present day value from Reunion) we end up with $2,8*10^4$ km^3 or 0,8% of the Deccan volume. This figure may be too high, since much of the iridium deposited on land eventually may end up in the ocean. No terrestrial K/T boundary has so far been found to show Ir enrichment (the American one happened too late).

A group of microbiologists wrote an article in which they pointed out, that by microbiological processes it would be possible to concentrate iridium into an anomaly provided that the iridium was available. The Ir anomaly is connected with the collapse-layer, which most often coincides with the extinction horizon. It is not the case in Israel where the extinction level occurs earlier than the collapse-layer (the latter is an organic-rich horizon).

The timing of the Ir-bearing basalt is very shortly before the K/T boundary. So there seems to be an explanation for the anomaly other than a meteoritic impact (which never took place!).

Now to some of the small side effects from the postulated meteoritic impact that time and again has called upon the sensational headlines:

1) Shocked quartz, which is ’only’ found in connection with meteoritic impacts.

It is undoubtedly so, that when a meteorite impacts into quartz-containing rocks, quartz grains with micro-lamellae with characteristic directions are formed. The micro-lamellae consist of diaplectic (shocked) glass and are also found after larger subsurface TNT and atomic explosions. This has led to a larger literature regarding presumed meteor craters back in earth history. If one finds shocked quartz, then it is a meteoritic crater. This is, however, not so! A series of rhyolitic ash beds of different ages have been found to contain shocked quartz also. We now know seven examples of this.

Admittedly, not all rhyolitic ash beds contain shocked quartz, as it depends on the composition of the rocks overlying the explosion site. If a meteorite impacts rocks without quartz, you do not find shock quarts. The same goes for a rhyolitic volcano. We may talk of an ’upside down’ impact. Shocked quartz cannot be used as conclusive evidence for a meteoritic impact.

2) Tektites.

When a meteorite impacts, smaller drops of melted rock are created. They are sprayed and may fall far from the impact site. The temperature of the material is very high and the surfaces of the drops, that may reach cm-size, often show a characteristic pitted surface. As the temperature is high and the oxygen content of the atmosphere is high, (21%) the material is being oxidised. If the glass contains carbon, it will be oxidised and one shall not expect to find a content of elementary carbon (graphite) in it.

Scientists supporting the impact hypothesis have interpreted spherules found at the marine K/T boundaries as being diagenetically altered micro-tektites. However, closer examination demonstrates that the so-called microtektites are sitting inside spherical algal skeletons. They are actually diagenetically infilled algal skeletons belonging to a group that have been called ’disaster species’. They occur in enormous amounts when their enemies are in trouble. They are also present at the other large mass-extinction at the Permo-Triassic boundary, where the same phenomenon occurs. Depending upon the local chemistry on the seafloor the skeletons may be filled by different minerals.

In the Mexican Gulf, beds containing spherules have been found. They have been declared altered micro-tektites. If such spherules are sectioned (some are mm size) one observes that they are full of vesicles. They have nothing to do with tektites. They contain small, hollow graphite spheres. If one dissolves basaltic volcanic glass one will end up with a residue of up to 15-micron hollow graphite spheres. They are sitting as a coating inside gas vesicles and would appear to have formed by the splitting of CO into CO_2 and elementary carbon (the Boudouard reaction). Free carbon does not exist in tektites. The spherules from the Caribbean are volcanic beads (Pele’s Tears). They are filled with gas-vesicles and many can float on seawater (some even on fresh water). Thus, they are volcanic products, and unrelated to meteorites.

3) Ni-rich spinels

Inside the spherules that have formed inside the ’disaster algae’ at the marine boundaries, one sometimes finds small branching crystallites. They consist of iron-nickel compounds with spinel structure. Such crystallites can be created by heating an iron-meteorite in an oven. Their presence in the spherules has been taken as an indication of an impact. However, they have a different chemical composition from place to place, and since they are sitting inside the filled algae it is evident that they formed where they are sitting today. The chemical difference from place to place also means that one has to suppose that each place had its own meteorite, in order to explain the difference.

4) Extra-terrestrial amino acids.

At Stevns Klint, so-called extra-terrestrial amino acids have been found above and below the Fish Clay, but not in the Fish Clay proper. Such amino acids are common during fire-processes and their relevance for the K/T boundary is rather hazy.

As the dream about the ’bomb’ as the killing agent is incorrect, we have to look into other mechanisms, and so far, I have avoided the dinosaurs because that needs lengthy explanations.

In the terrestrial deposits before the K/T boundary, a change in the composition of the dinosaur fauna in France takes place. This happens at the level of incised valleys 700,000 years before the K/T. Southern France has the same incised valleys as in North America and it is here that the famous bone-beds that are being excavated in the Aude Valley are found. At this level a change takes place from a fauna with many titanosauriid forms (4-legged forms with long tails and long necks) to hadrosauriid forms (duckbilled dinosaurs). The French deposits are ’red-beds’. In these, the dinosaurs laid their eggs, which are found rather commonly. The sediments are red to reddish brown. There are occasional horizons with yellow or blue-green vertical traces after plant roots. Plant roots breathe and consume oxygen; they do not produce it. Therefore, around the root traces are reduced iron and therefore the other colours. There was occasional vegetation but the find of microscopic desert roses shows that is was a desert like environment.

When dinosaur eggshells are collected level by level from older to younger sediments there is, around 350,000 years before the K/T, an increase in the frequency of black eggshells. When collected further down, the frequency of black eggshells is around 1%, while it increases to between 10 and 15%, and the very last level contains black eggs only. The black colour is not confined to the surface of the eggshells, but stains the whole shell as seen in broken pieces. Bird's eggs with colours are not coloured throughout the shell, but only on the surface.

Black dinosaur eggshells have been found in China, India and France. Chemical analysis of the black eggshells, show that they contain silver (silver sulphide). The amount is on the ppm level, which is 1000 to 10,000 times the background silver value in the surrounding sediment. The find of silver-bearing eggshells in different regions and in different species tells us, that it is independent of species and must be caused by later processes. In spite of the goose known from fairy tales, the dinosaurs did not lay silvery eggs!

The hatching mechanism must be looked into. Dinosaur eggs (and alligator, crocodile, turtle etc.) eggs are all highly porous. Even when the shells are several mm thick, they still have very high water vapour conductivity. A fresh alligator egg and a bird's egg put together in a heating cupboard at 40° C show a water-loss of the alligator-egg that is 10-15 times that of the bird's egg. The Florida alligators solve the problem by laying their eggs in moist compost, which they scrape together in the swampy areas where they live. The high water vapour conductivity prescribes, that the eggs must be hatched under moist conditions without exposure. The Everglade crocodiles are also able to use wet sand along rivers for their hatching. In the Indonesian region is a crocodile, which can knock down vegetation in the back mangroves. It waits until the primary fermentation is over because that leads to temperatures in the early 60's. When the temperature drops and cellulose fermentation takes over, temperatures drop to the early 30's. It then lays the eggs and starts waiting for the outcome.

The dinosaurs did not deposit their eggs exposed. They used wet sand or compost. It is, however, not easy to get compost in a desert-like environment, where we find their nests today. If you look at an elephant from behind, you will observe a big belly full of pre-fermented compost. Therefore, it is an obvious possibility, that plant-eating dinosaurs used their dung as compost material. The meat-eating dinosaurs were confined to parasiting on other's composts or to use wet sand. The parasite behaviour was just found in Portugal, where meat-eaters parasited upon crocodile-compost nests.

What is the origin of the silver? If an egg is no good and for one or another reason will not develop and hatch, it will start rotting. This leads to production of H_2S. Along with the fermentation of the compost all trace elements from the compost will be brought into contact with the rotting egg and all elements that can form sulphides will be precipitated in the shell. Silver sulfide is difficult to bring into dissolution. Think of a silver fork, which has been in contact with a fried egg. The silver sulfide has to be polished off or you have to use chemical means to clean it.

Thus - a black egg is one that never hatched. That all the eggs from the last level in France are black means that they never hatched. During the period of increased non-hatching of eggs, there were still eggs that were hatched. Among humans and animals it is so, that all chemical loads such as arsenic etc. show up in the hair and nails. We are de-poisoning ourselves. We therefore looked for eventual elements in the white eggshells in the period where the black eggshells were increasing in numbers. We found a surprisingly high content of the element selenium.

Selenium is an element, which is essential to humans and other animals. Experiments with hens, however, demonstrated that increased concentration of selenium strongly reduced the hatching of the eggs, through increased non-development of the foetuses. Those who looked into this made investigations of blood, brain, kidney, albumen and yoke. The only thing they did not investigate was the eggshell. Who cares? Therefore, we had to run our own experiments with hens suffering selenium load. From the literature, it appeared that 20-ppm selenium had a poisonous effect, and therefore the hens got 15-10-5 ppm and as a control chicken-fodder from the local Coop. The results were perfectly clear: irrespectable of the load, they invariably showed 1:2 in concentration of selenium between eggshell and yoke. We cannot make experiments with living dinosaurs, but their nearest relatives (the birds) did not become extinct; they just put on feathers and climbed into the trees.

The next question is of course where did the selenium come from? The analysis of the extrusion products from Kilauea, Hawaii in 1983 showed that the element that was most strongly enriched relative to Hawaiian basalt, was selenium. In the volcanic flying dust, the concentration relative to the basalt was raised by a factor of 10^7. How much did a plant-consuming dinosaur eat per day?

The Zoological Garden in Copenhagen has told us that a 4 ton African elephant eats 200-400kg plant material per day. If you want, you can scale it to a 20 ton dinosaur! This again you may convert into plant leaf area, which a plant-eating dinosaur would consume every day. If the leaves were carrying Se-bearing volcanic flying dust, one may assume a reduced hatching. One may argue, that there will always be someone who can survive this! However, one has to consider, that a Se-load is not constant but arrives in pulses. Thus, the 'normals' that just made it will get a renewed knock on the head, since it is not a constant pressure on the populations. A drop in hatching of 10% corresponds to the reduction in the crop of African elephants when the poaching for ivory was at its highest. In few years, the elephant was declared an animal facing extinction. The reduction in crop lead to the disappearance of the French dinosaurs 350,000 years before the K/T boundary. Interestingly enough the dinosaurs in India vanished at the same time. The dinosaurs in North America stayed on and the same goes for the Chinese ones. The very last American dinosaur (probably a Triceratops) lies 2.25 m beneath the K/T boundary while the three last nests with black eggs are 90,000 years below the K/T boundary in South China. We do not know of any younger dinosaurs. When talking about dinosaurs, we do not recognise loose bones and teeth. They are easily re-deposited. We recognise only: eggs in nests, footprints and articulated skeletons.

Thus, the dinosaurs disappeared at different time in different areas, and we are forced to suppose that they were unable to tolerate very rapid climatic changes coupled with the rapid drops in sea level. Their living space was strongly reduced following the sea level drops. It leads to other drainage patterns of the land areas, whereby the available feeding areas were reduced drastically. The observation, that each of the different families only had a single representative left at the end of the Cretaceous is in good agreement with this. We therefore conclude that the disappearance of the dinosaurs is linked to reduced hatching and limitation of living space.

This explanation is not as 'sexy' as the Heavenly Stone (or the 'bomb') but it fits well with the observations. And that, in a way, is very nice!