



Causes of mass extinctions - With special reference to vanishing of dinosaurs

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Abstract: The causes of mass extinctions have been currently reviewed with state-of-the-art information on new hypotheses dealing with the disappearance of creatures as a result of sudden (catastrophic) and/or gradual changes in environments. A special reference to vanishing of dinosaurs is detailed.

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1. Introduction

When someone watches the sky in a bright, cloudless night he will notice a number of stars that are scattered in an amazing view. These stars are estimated as nearly as 130 billion stars, which belong to the Milky Way Galaxy. In contrast, the view of the Earth from the space looks like a pale blue dot; according to Carl Sagan (1995).

The first idea that comes to mind, as a geologist, is thinking of the effect of collision of an asteroid with Earth!! We should affirm that human is searching for safety on the Earth; so he tries to save the Earth or, at least, to minimize dangerous effects resulting from catastrophes related to natural processes such as earthquakes and volcanoes, and artificial processes made by man himself. In parallel to his cautious action, surprisingly in an opposing manner, man is accelerating extinction of organisms in our world (see Elewa, 2008c).

It is common to geologists, and to some other scientists of close interest, as well as interested readers, that there are at least five major mass extinctions (Raup and Sepkoski, 1982), adding to a number of minor extinctions, occurred throughout the history of life on Earth. These extinctions arranged from older to younger in the following way:

1. Ordovician-Silurian mass extinction
2. Late Devonian mass extinction
3. Permian-Triassic mass extinction
4. Triassic-Jurassic mass extinction

5. Cretaceous-Paleogene mass extinction (e.g. K/Pg mass extinction)

Nevertheless, some geologists believe in additional major mass extinction that occurred, according to their belief, at the end of Cambrian (Late Cambrian mass extinction).

Interestingly, Prothero (1998) mentioned that if 5 to 50 billion species have lived on this planet, but only about fifty million are alive today, then 99.9% of all species that have ever lived are now extinct!! He added that statistically this percent might indicate, at first approximation, that all species are extinct!!

Douglas Erwin (2001) indicated that mass extinctions seem to account for the disappearance of less than 5% of all extinct species; even though, the evolutionary opportunities they have created have had a disproportionate effect on the history of life.

Elewa and Joseph (2009) discussed the history, origins, and causes of mass extinctions, from the creation of our planet to modern times. Their detailed review included mass extinctions during the Ordovician, Devonian, Permian, Triassic, and Cretaceous, and prior to and during the Cambrian Explosion, as well as the ongoing sixth mass extinction.

Noort and Elewa (2011) introduced a new theory based on the celestial factor to explain and to estimate the size and frequency of all extinctions over the entire period of the fossil record.

2. Most widely supported hypotheses

In the following, a brief focus on the most widely supported causes has been shown to define how each of them is assumed to cause more than one of the major mass extinctions of the fossil record, and to which extent these causes are complicated.

In fact, still, the causes of these mass extinctions are subject to several disputable opinions. If we summarized the most acceptable causes of these extinctions we will find that they are applicable, according to many authors, to the majority of mass extinctions of the fossil record. These causes, without any particular order, are mainly:

1. Global cooling
2. Major glaciation
3. Sea level drop
4. Global anoxia
5. Volcanic eruptions
6. Asteroid, or extraterrestrial bolide, impacts

- Global cooling

This reason is mentioned by many authors to cause or, at least, control some other reasons leading to all major mass extinctions; from the Late Ordovician through the Late Devonian, Late Permian, and Late Triassic to the Late Cretaceous. These authors suppose that global cooling triggered glaciation and significant lowering of the sea level, therefore deep marine organisms as well as organisms favoring warm conditions died.

- Major glaciation

Glaciation itself is considered as a dependent factor, in which it is controlled by global cooling. Sheehan (2001) confirmed that the cause of Ordovician mass extinction was a brief glacial interval that produced two pulses of extinction. Saltzman Matthew (2009) argued that volcanic weathering led to draw down $p\text{CO}_2$ and resulted in a cooling episode, which produced the well known End-Ordovician (Hirnantian) glaciation. It is remarkable that both rapid warming and glaciation might be occurred during the Permian; as stated by several authors.

- Sea level drop

Sea level drop means decreasing of sea level; in other words, it refers to sea level fall. Resembling glaciation, the sea level drop is based on global cooling, in which global cooling leads to lowering of sea level; in contrast, global warming causes sea level rise. Therefore, creatures that cannot acclimatize with global

changes in climate and/or environmental conditions die. On the other hand, Landzy et al. (1977) applied the catastrophe theory to the Permian extinction of marine invertebrates, and concluded that a reduction in oceanic salinity was a more significant factor in the extinction of marine invertebrates than was a reduction in the area of shallow seas.

József Pálffy and others (2000) declared that the end-Triassic biotic crisis on land appears to have preceded that in the sea by at least several hundred thousand years. This notice needs more research to know the exact reasons for that situation!! If reduction in oceanic salinity was significant in the extinction of marine invertebrates at the end of Permian, then, supposing accuracy of the used age dating techniques, what are the significant reasons that led to accelerate the extinction of land biota earlier than marine forms at the end of Triassic?? Is it anoxia? The answer is still debatable; however one of the probable reasons is introduced by Ward (2006), who argued that dinosaurs became the monsters that ruled the Earth for more than 60 million years -- and survived mass extinctions that destroyed many other species -- because they developed respiratory systems far more efficient than other terrestrial creatures.

- Global anoxia

Global anoxia means reduction of oxygen in oceans below normal levels. It is believed that global anoxia may be one of the decisive causes of Devonian mass extinction. Also, Wignall and Twitchett (1996) stated that the world's oceans became anoxic at both low and high paleolatitudes in the Late Permian that may have been responsible for the mass extinction at that time. Samar Abbas and colleagues (2000) asserted that recent evidence quite convincingly indicates that the Late Permian biotic crisis was in fact a binary extinction with a distinct end-Guadalupian extinction pulse preceding the major terminal End-Permian Tartarian event by 5 m.y. They added that anoxia appears to be closely associated with each of these End-Paleozoic binary extinctions. Alternatively, some authors attributed the Cenomanian/Turonian extinction to global anoxia. Bing Shen (2008) clued that during the Cenomanian/Turonian times the enhanced flux of volcanic ash inputted micro-nutrient iron into the ocean, fertilizing surface waters and generating a global phytoplanktonic

bloom, which in turn depleted oxygen in deep ocean.

James Castle and John Rodgers (2009) introduced another opinion concerning anoxia. These authors concluded that characteristics and occurrences of algae in modern aquatic environments and observations from the fossil record propose that toxin-producing algae were present in the geologic past and were an important factor in Phanerozoic mass extinctions. They suggested that the large mass of organic material produced by algal blooms can lead to oxygen depletion during decay, which indirectly causes death of some biota.

- Volcanic eruptions

Some scientists consider volcanism as one of the most important reasons led to mass extinctions in the fossil record (see MacLeod, 2000, 2001). Researchers pointed out that ash and dust resulted from these eruptions prevented sunlight, then a distinct drop in temperature and plant production occurred, and poorly adapted organisms (including dinosaurs), accordingly, died. It is also notable that some other scientists consider global anoxia to be triggered by volcanism (see the above section on global anoxia).

Vincent Courtillot (1999) was one of those who suggested that cataclysmic volcanic activity can be linked not only to the K/Pg mass extinction but also to most of the main mass extinction events in the history of Earth.

Some very large extrusions of sheet lava are considered to have had an effect on climatic change. It is interesting to have a look over the subject of the "Deccan Traps" of India, which French researchers think to have been more significant than the Haiti bolide.

- Asteroid impact

If you are curious about astronomy and would like to know the relationship between asteroids and catastrophic events that may occur, you may like to have a visit to the following website:

<http://curious.astro.cornell.edu/comets.php>.

There, you can simply know the difference between asteroids, comets, meteors and meteorites. In spite of this, what is related to my article is the question that was asked to Prof. Britt Scharringhausen (Professor of physics and astronomy, Beloit College in Wisconsin); what may happen if an asteroid of about 10 km in diameter hits either land or ocean on Earth? She clearly said that many species of animals--

including the human race, if we aren't both lucky and resourceful!--will die out, either in the initial catastrophe, or in the ensuing years due to lack of food and the general devastation of the environment (for details about how this devastation of the environment can occur, please visit the above mentioned website).

However, no doubt, Alvarez et al. (1980) have entirely changed our thinking towards the causes of mass extinctions by referring to asteroid impact as a strongly possible reason responsible for this phenomenon. Even though, there are controversial opinions on this subject matter. For example, another team of scientists believe in the non-impact hypotheses; some others believe in multiple causes (see Molina et al., 1996; Twitchett, 2006; Elewa, 2008a, b; Elewa and Dakrory, 2008a, b). Alvarez and his team focused their study on measuring iridium, which is very rare on Earth's surface but more common in the composition of asteroids. However, iridium is also common in rocks from deep Earth; therefore some scientists presume that the presence of this iridium in the dinosaurs-bearing beds may indicate volcanism to vanish these giant reptiles. Another context lies in the argument of whether single meteorite impact or two successive impacts caused the K/Pg mass extinction.

One more opinion was introduced by Norman MacLeod (2000, 2001), who considered tectonic factors - giving rise to flood-basalt volcanism and sea-level fall - appear to exhibit the greatest level of association with large-scale extinction events over the course of the last 600 million years. He believes that extraterrestrial impacts have certainly played an important role in Earth history and may have enhanced the 'death of the dinosaurs.' However, asteroid impacts, according to his opinion, do not appear to be the primary agents responsible for the overall patterns in the geological extinction record.

3. Other hypotheses

The other hypotheses include: Sustained and significant global warming (Mayhew et al., 2008), clathrate gun hypothesis (Hecht, 2002), hydrogen sulfide emissions from the seas (Kump et al., 2005), oceanic overturn (Wilde and Berry, 1984), a nearby nova, supernova or gamma ray burst (Melott and Thomas, 2009), and plate tectonics (Hooper Virtual Paleontological Museum. Retrieved 16 July 2012).

4. The Mystery of Dinosaurs Extinction!!

One of the most attractive and strange opinions assumed that sex disability was responsible for extinction of dinosaurs. Close (1988) disputed this idea and stated that it is not acceptable to attribute the disappearance of dinosaurs, since 65 million years, to their sex disability!! He rejected this assumption by explaining how the male have to keep one of his legs on ground during sex to prevent killing the female. It is astounding, however, that some recent reptiles, which have different sizes for males compared to females, show correlation between kind of gender and temperature, in which higher temperatures merely produce individuals (either males or females) that have bigger body size, and vice versa. Consequently, there will be no reproduction, and hence extinction of this group must occur!!

Actually, there are several unpersuasive, and still disproved, theories and hypotheses on the extinction of dinosaurs. I'll mention some of them to present condensed summary on this subject matter. Subsequently, I'll finalize with my opinion and leave the decision to readers; which is acceptable and which is feeble. Just, before proceeding, you should think of the complications that make this job difficult!! Jablonski (1994) mentioned two important problems that disabled agreements of causes of mass extinctions; these are:

1. Difficulties in resolving the fine details of taxon ranges, and abundances immediately prior to and after an extinction boundary; and
2. The scarcity of simple, unitary cause-and-effect relations in complex biological systems.

Returning to theories and hypotheses, we can summarize some of them in the following:

1. Asteroid impact has killed dinosaurs.
2. Volcanism caused dinosaurs extinction.
3. Abrupt climatic changes (e.g. changes in temperature from low to high, and vice versa).
4. One of the newly presented ideas is the role of Jell-O® in the mass extinction of dinosaurs. This idea explains the nutritional impact of Jell-O® on animals whose digestive and circulatory systems were unprepared for it.
5. Another idea refers to mammal competition. The believers of this idea attributed the vanishing of dinosaurs to eating their eggs by small mammals!!

6. A strange idea explains how dinosaurs have killed themselves by their spines due to mistaken position when they intend to have a rest on the ground.
7. A minor opinion suggests that insects have killed dinosaurs.

Whatever the reason of extinction of dinosaurs, it is necessary to refer to the terrible effects of the most acceptable reason "extraterrestrial bolide impact". Scientists already studied, and still discovering, these effects and discussed the chain events that might occur after the impact. As specialists know, the effects include the following:

1. Making small or big crater in the area of collision, according to the size of the meteorite that stroke Earth,
2. This crater hurls out small rounded masses of glassy material (e.g. tektites), and
3. Tsunamies occur as a result of shock waves that are sent through the crust and upper mantle.

Not only the above events are very dangerous, but also the following long-term effects are horribly destructive:

1. The heat produced by the meteorite when penetrates the atmosphere, and the heat wave resulting from tektites cause enormous fires;
2. Soot and dust prevent sunlight, and consequently photosynthesis; this leads to disturbing food chain;
3. Preventing sunlight causes the so-called "Nuclear Winter Effect";
4. There are, however, some other processes occur, like potential injections of CO₂.

Thompson and Crutzen (1988) examined the acute effects of a large bolide impact using a global three-dimensional atmospheric circulation model, and could conclude some results related to temporal and geographical evolution of land surface temperature effects, stratospheric ozone depletion, and nitric acid formation.

To be specific, only the K/Pg mass extinction is strongly ascribed to the impact; even though, there are debatable opinions concerning this topic.

Regardless, the acceptable hypothesis to me is the combination of extraterrestrial bolide impact and environmental changes to interpret disappearance of dinosaurs at the K/Pg boundary (multi-causal scenario or the Press-Pulse Theory of Arens and West (2008)), where impact led to abrupt extinction, while environmental changes

generated gradual disappearance. Generally, I support the opinion of Elewa and Dakrory (2008a), who are convinced that the combination of multiple reasons could be acceptable to both believers in impacts, or catastrophes, and those approve the gradual effects.

5. Did dinosaurs survive mass extinction?

Fassett et al. (2011) used a new direct-dating method called U-Pb (uranium-lead) dating to determine the age of two dinosaur fossils from the San Juan Basin of northwestern New Mexico and southwestern Colorado, United States. They could successfully date the age of these two dinosaur fossils by comparing their results with previous age-dating methods. This claim is asserted to establish the survival of dinosaurs into the Paleogene.

However, Renne and Goodwin (2012) debated this suggestion of Fassett et al., and argued that it is entirely possible that the fossil fragments studied by Fassett et al. were reworked postmortem.

Moreover, Koenig and his colleagues (Koenig et al. 2012) stated that Fassett et al. ignore previously published work that directly questions their stratigraphic interpretations (Lucas et al., 2009), and fail to provide sufficient descriptions of instrumental, geochronological, and statistical treatments of the data to allow evaluation of the potentially complex diagenetic and recrystallization history of bone. These shortcomings led them to question the validity of the U-Pb dates published by Fassett et al. and their conclusions regarding the existence of Paleocene dinosaurs. Based on their comment, Koenig et al. concluded that Fassett et al. have failed to provide the extraordinary evidence needed to support the extraordinary claim that dinosaurs survived the K/T impact event and lived into the Paleocene.

In the same time, Ludwig (2012) mentioned some doubt about the method used by Fassett et al. to extract U/Pb ages from the U/Pb isotopic analyses.

In response to these comments, Fassett et al. (2012a, b) replied to defend their opinion. But still the story did not end.

It is worth mentioning, that Wilkinson et al. (2012), clued that sauropod megaherbivores were responsible for the greenhouse warming around 150 million years ago.

6. Minor mass extinctions

Distinguishing the “Big Five” does not mean that there were no minor extinctions. Some of these bioevents are those of the Silurian. Several scientists consider that Silurian represents one of the quiet and stable periods of Earth history; however Calner (2008) mentioned opposing opinion through interesting review of the subject. Another case is presented by Abdelhady (2008), for the Cenomanian/Turonian macroinvertebrates, who noticed evidences for selective extinction at the C/T boundary. Julien Louys (2008) introduced excellent examples of Quaternary faunal extinction in Southeast Asia. Authors are still working on causes and effects of these minor extinctions, but this is not our point of interest in this article.

7. Current mass extinction

Day after day, several articles and news introduce evidences to clue that human activities are responsible for the current mass extinction. David S. Wilcove et al. (1998) used five major categories (including: overexploitation; habitat destruction; the introduction of non-native (alien) species; the spread of diseases carried by alien species; pollution) to quantify threats to imperiled species in the United States of America. Elewa (2008c), in his edited volume on mass extinction, stated that man is accelerating extinction of organisms in our world. How it is pity to know that man is responsible for this big disaster!!

Albeit, the possibility that asteroid impact could be one of the leading causes to current mass extinction is still acceptable. Christopher Chyba et al. (1993) mentioned that the explosion over Tunguska, Central Siberia, in 1908, which released 10 to 20 megatons, typically represents a fate for stony asteroids tens of meters in radius entering the Earth's atmosphere at common hypersonic velocities. Richard Firestone et al. (2007) provided evidence for an extraterrestrial (ET) impact event at $\cong 12.9$ ka, which is suggested to cause abrupt environmental changes that contributed to Younger Dryas (YD) cooling, major ecological reorganization, broad-scale extinctions, and rapid human behavioral shifts at the end of the Clovis Period of North America. Richard Firestone and Allen West declared in the year 2005, through the media (based on Lawrence Berkeley National Laboratory release), that a distant supernova that exploded 41,000 years ago may have led to the extinction of the mammoth.

8. Avoiding mass extinctions

One of the recommended options to avoid mass extinctions is introduced by Michael Rosenzweig (2005), who said that preserving Earth's diversity of species requires that conservation biology turn much of its attention to reconciliation ecology, which is the science of sharing our habitats with wild things. In another article that was written by Fortune Ihunweze (2009), the author suggested that proper environment impact assessment must be carried out before any project is executed. As well, concerted effort must be made by government and industrialists to cut down on the emission of polluting gases to tolerable levels. Internationally agreed standards for emissions and waste discharges from industries must be kept to (see the following website: http://ezinearticles.com/?expert=Fortune_Ihunweze). He mentioned other suggested solutions that are focused on our behavior towards environment. No doubt, if we could be changed to better behavior, several problems related to this subject will be easy to solve. In the same manner, Elewa (2008c) proposed seven important steps to avoid the current mass extinction; these are:

1. Looking to peace, between peoples, and between them and other creatures, as a strategic plan;
2. Minimizing all kinds of pollution to the least by searching for substitutive products that are not harmful to the environment;
3. Keeping uncommon animals and plants from extinction by making natural protections in different areas of the world;
4. Encouraging scientists, especially biologists, to shed more light on this serious problem through the media;
5. Activating the environmental program of the United Nations (UNEP) in the field of protecting plants and animals from loss;
6. Keeping stability of nature by stopping unsafe programs leading to disturbing our environment; and
7. Studying the major mass extinctions of the fossil record to know the reasons led to these awful bioevents.

In conclusion, I have tried to introduce a short, condensed review article, with simple and understandable manner so as to be understood by a broad range of scientists, on one of the mysterious phenomena that occurred and may occur in the future "Mass Extinction"; with

particular focus on extraterrestrial bolide impact as one of the strongly acceptable causes of dinosaurs extinction as well as current mass extinction.

Thereafter, just a question rises to mind: what is the better to human being? Thinking for avoiding danger or looking for utterly perishing our life!!!

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