THE MYSTERY OF THE DINOSAURS: THE EARTH'S ELECTROMAGNETIC FIELD MAY EXPLAIN THEIR GIANTISM AND EXTINCTION

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Abstract

Why dinosaurs became so large and why they became extinct are two of the great mysteries of biology. However, no theory has yet succeeded in explaining the biotic transitions adequately. In a previous meta-analysis, we found that exposure to an extremely low frequency electromagnetic field (ELF-EMF) was associated with an increase in animal body weight. In the present paper, we propose that the large body size of the dinosaurs was caused by ELF-EMFs generated by natural phenomena: geomagnetic storms, volcanic activity, earthquakes, or Schumann resonance. To support this hypothesis, we researched long-term data on changes in these processes. We found that there was a high level of crustal change during the age of the dinosaurs. We propose that Ultra-low frequency (ULF) /ELF-EMFs produced by widespread earthquakes and volcanism caused the dinosaurs to become larger, then when these phenomena were no longer so prevalent, the dinosaurs became extinct for a number of reasons, among them the loss of ULF/ELF-EMFs.

(Keywords)
Bergmann's rule, Rensch's rule, Cope's rule, magnetic field, ELF, body size, dinosaur, extinction, giantism

1. Introduction

Why dinosaurs became so large and why they became extinct are two of the great mysteries of biology. The Cretaceous-Tertiary extinction, during which the dinosaurs died out, ranks as one of the five largest extinction events of the Paleozoic. At the time, the earth was undergoing changes in global climate and sea level, and was subject to events such as massive volcanism and bolide impacts. Many causes have been hypothesized for the mass extinction, including bolide impacts [1-3], massive volcanism [2-4], sea level change [2,3], and climate change [2,3]. However, no theory has yet succeeded in explaining the biotic transitions completely.

In a previous article [5], we focused on the relationship between extremely low frequency (3-3000 Hz) electromagnetic field (ELF-EMF) exposure and animal body size, given that Bergmann's rule stipulates that organisms will tend to be larger at higher latitudes, where the earth's geomagnetic field (typically around 50 μT, range 20-90 μT) is more than twofold stronger than at lower latitudes. In that article, we reviewed four papers in which animals exposed to ELF-EMFs and animals that were sham exposed were compared over a period of 2 years. Meta-analysis revealed that ELF-EMF exposure had a statistically significant positive association with weight in males ($p = 0.0007$), but not in females ($p = 0.25$). Thus, ELF-EMF seems to cause an increase in body weight in males but not females, which might explain Rensch's rule, which states that in many animal groups, when the male is larger than the female, sexual size dimorphism (the ratio of male to female size) increases with body size, but in groups in which the male is smaller than the female, sexual size dimorphism decreases with body size). At higher latitudes, the earth's geomagnetic field is more than twice as strong as at lower latitudes, which would explain Bergmann's rule (the tendency towards size increase with increasing latitude). Similarly, a strengthening of environmental electromagnetic or magnetic field (MF) over evolutionary time might possibly explain Cope's rule (the tendency towards size increase within phyletic lineages). In the above-mentioned article, we mainly focused on the relationship between the earth's geomagnetic field and Bergmann's and Rensch's rules.

Ultra-low frequency (ULF) (0.03-3 Hz) and ELF-EMFs are generated by geomagnetic storms [6], volcanic activity [7], earthquakes [7], and Schumann resonance [8]. The human brain uses a range of frequency patterns, which can be detected using electroencephalography; The frequency range of the electroencephalogram rhythms coincides with the frequency range of the Schumann resonance signal (0–45 Hz) [9]. Thus, ULF/ELF-EMFs may have an effect on evolutionary processes in animals, at least with respect to animal brains [9]. So, in the present study, we focused on a possible relationship between Cope's rule and ULF/ELF-EMFs. Recent studies suggest that Cope's rule holds for a variety of taxa, including Cenozoic mammals [10-12] and dinosaurs [13]. Therefore, we researched the relationship between giantism and ULF/ELF-EMFs in dinosaurs.

2. Materials and Methods

It was not possible to obtain long-term data on Schumann resonance, because it is caused by thunderstorms. Therefore, we obtained long-term data relating to geomagnetic storms, volcanic activity, and earthquakes. For geomagnetic storms, we obtained data relating to solar activity, because the arrival of high-speed solar plasma and the associated shock wave near the Earth causes geomagnetic storms [6]. We identified potentially relevant papers by performing a search of the Web of Science database (1990–December 2007). The search terms used were ‘Cretaceous’ and ‘sun’, ‘Cretaceous’ and ‘solar’, and ‘Cretaceous’ and ‘volcanic’, and the search was restricted to papers in English or Japanese.

3. Results

Well-documented variations in the $^{15}N/^{14}N$ ratio in lunar surface samples are apparently the result of secular increases in that ratio in the solar wind during the past few billion years [14]. In the age of the dinosaurs, the $^{15}N/^{14}N$ ratio was at a high level; however, the material has been determined to be non-solar N [14].

During the late Carboniferous (~250 million years ago, Ma), continents were assembled in a single unit called Pangaea, surrounded by a global ocean named Panthalassa [15]. This configuration remained quite stable for about 70 million years, but 190–180 Ma, the super-continent Pangaea began to rift apart to form the central Atlantic Ocean, with North America rotating away from Africa [15]. As Pangaea broke apart, the tectonic plates of the earth moved against each other, causing earthquakes and volcanic activity. The high level of geologic activity at this time is reflected in the volume of volcanic rocks produced, increasing from 250 Ma and then slowing down around 70 Ma, when dinosaurs were dying out (Fig. 1) [16].

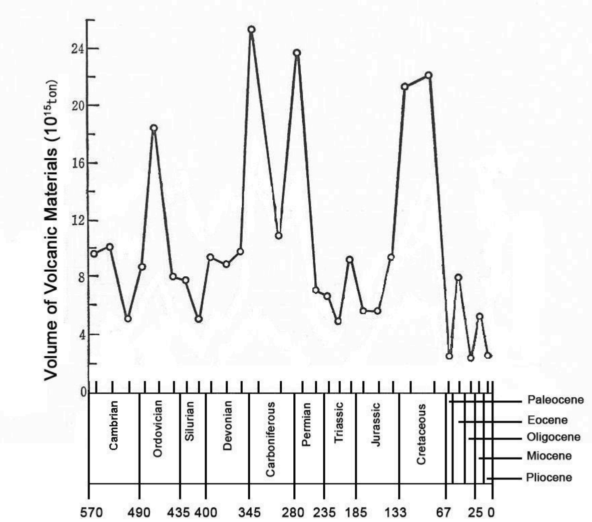

Figure 1. Long-term changes in the volume of volcanic material produced on earth [16]

4. Discussion

In our review of the literature, we found that crustal changes were at a high level in the age of the dinosaurs. Crustal changes such as volcanic activity and earthquakes generate ULF/ELF-EMFs. So, we hypothesize that the ULF/ELF-EMFs generated by volcanic activity and earthquakes caused the dinosaurs to become larger.

Lower frequency EMFs, especially the ULF-EMFs generated by volcanic activity and earthquakes, can propagate over long distances [17] and animals seem to be most sensitive to electromagnetic fields below 10 Hz [6,18,19]. Therefore, it seems likely that lower frequency ULF/ELF-EMFs would have the greatest effect on the body weight gain of animals.

Regarding the mechanism of weight gain, it is interesting that mild increases in plasma thyroid hormones (e.g., thyroxine) [20] and prolactin [21] have been found in pregnant lactating dairy cows exposed to ELF-EMF. Thyroxine is known to play key roles in growth, metabolism, reproduction, and somatic differentiation in developing and adult animals [22]. Also in pregnant lactating dairy cows, exposure to the electric component of these fields alone (10 kV/m) did not affect either prolactin or thyroxine [23]. It is possible that MFs exert an effect on body size via plasma thyroxine and/or prolactin. In fact, injections of prolactin and thyroid hormones have been found to promote weight gain in male reindeer [24].

It is also possible that EMFs exert an effect on skeleton size via alteration of the proliferation and activity of bone cells. In support of this hypothesis, pulsed EMF stimulation has been used clinically for more than twenty-five years for the treatment of patients with delayed fracture healing and non-unions [25]. Furthermore, a substantial number of in vitro studies have shown that EMFs have positive effects on the proliferation and activity of bone cells [25].

Yamashita and Saito demonstrated that 100 mT static magnetic fields have an effect on mitochondria; they found that energy activity and cell respiration in mitochondria that were exposed to a MF increased by factors of 1.5 and 1.3, respectively, compared with the sham control group [26]. It seems that mitochondria are activated by MF and thereafter provide more ATP to some organelles in the cells of an organism [26]. Promotion of ATP synthesis by a MF would provide the energy to maintain a larger body size. That is, organisms would be able to use magnetic energy as well as other forms of physical energy.

There is a theory that high atmospheric O_2 caused insects to become larger in size during the Carboniferous period and low levels of atmospheric O_2 caused the dinosaurs to become larger in size during the Cretaceous [27]. The same source also proposed that the primary reason for the dinosaurs’ endothermy adaptation was not to maintain a constant temperature but to increase efficiency in a low-oxygen environment [27]. However, plants were also larger during the Carboniferous period [27]. For plants, high levels of atmospheric O_2 are harmful, so conditions of high atmospheric O_2 could not have caused the plants to become larger. Thus, the O_2 theory does not explain the giantism of both insects and plants, but ULF/ELF-EMF does explain the phenomenon: several studies have suggested that ULF/ELF MF may modify plant growth and development [28]. Furthermore, vascular plants adhere to Cope’s rule [29].

The volume of volcanic materials created was also high in the Carboniferous period, as well as in the Cretaceous period. During the Carboniferous period, animal gigantism is known to have existed. Carboniferous gigantism was most evident among a number of diverse lineages of flying insects, but was also present in other arthropod taxa, such as millipedes and arthropleurids, and among the terrestrial labyrinthodont amphibians [30]. Although insects are heterothermic animals, if the air temperature is high, their body temperature is correspondingly high. During the Carboniferous period, the air temperature was high [31], so they could have been subject to the effects of ULF/ELF-EMF. We believe that ULF/ELF-EMF may have affected a particular biological reaction that requires high temperatures to proceed.

Although the Cretaceous-Tertiary extinction is generally thought to have been caused by a combination of factors [2], we believe that a reduction in the prevalent ULF/ELF-EMF is one important factor. Turtle, lizard, and snake species were little affected by the Cretaceous-Tertiary extinction [32] and, correspondingly, they do not adhere to Bergmann's or Cope's rules. If these species are little influenced by EMF or MF, this would support our theory.

We propose that ULF/ELF-EMFs produced by intense earthquakes and volcanism caused the dinosaurs to become larger in size. Plants exposed to ULF/ELF-EMF also became larger, providing more food for dinosaurs. However, the prevalent level of volcanic activity lessened in the late Cretaceous (Fig. 1), meaning that dinosaurs were no longer subject to ULF/ELF-EMF, and, together with other changes in the environment, the loss of the ULF/ELF-EMF led to their extinction.

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