ἄνθρωπος
ΟΡΓΑΝΟ ΤΗΣ ΑΝΘΡΩΠΟΛΟΓΙΚΗΣ ΕΤΑΙΡΕΙΑΣ ΕΛΛΑΔΟΣ Γενάρης 1987 — Γενάρης 1990

GALACTIC CORE EXPLOSIONS AND THE EVOLUTION OF LIFE

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1. Introduction

It is known that at periodic intervals the cores of galaxies erupt explosively, spewing out intense volleys of cosmic ray particles. Our own Galaxy is no exception. Evidence suggests that these electron volleys, or "superwaves", propagate radially outward from our Galaxy's center virtually unimpeded by the interstellar medium. Upon reaching the solar vicinity, they can cause the intensity of the local cosmic ray electron background to increase by several orders of magnitude (LaViolette, 1983a, 1987). Even though cosmic ray electrons presently account for only one percent of the cosmic ray proton background intensity, during such an event the electron intensity could far exceed current proton intensity.

A study of the polar ice core record indicates that cosmogenic beryllium concentration (^{10}Be) increased on at least five occassions during the past 10^5 years; (see Figure 1). ^{10}Be is produced when cosmic ray particles impact nitrogen molecules in the Earth's atmosphere. Cosmic ray protons and their proton and neutron secondaries are the most efficient producers of ^{10}Be, although, the gamma ray secondaries spawned from incident cosmic ray electrons would also contribute to the production. Astronomical evidence suggests that the most recent peak, at the end of the last ice age (10 - 18 kyrs BP), involved an increase in Galactic cosmic ray electron intensity of up to 3×10^5 fold (LaViolette, 1983a). Such a flux would have been capable of producing an 80 fold increase in the ground level ionizing radiation intensity (to about 4 r/yr).

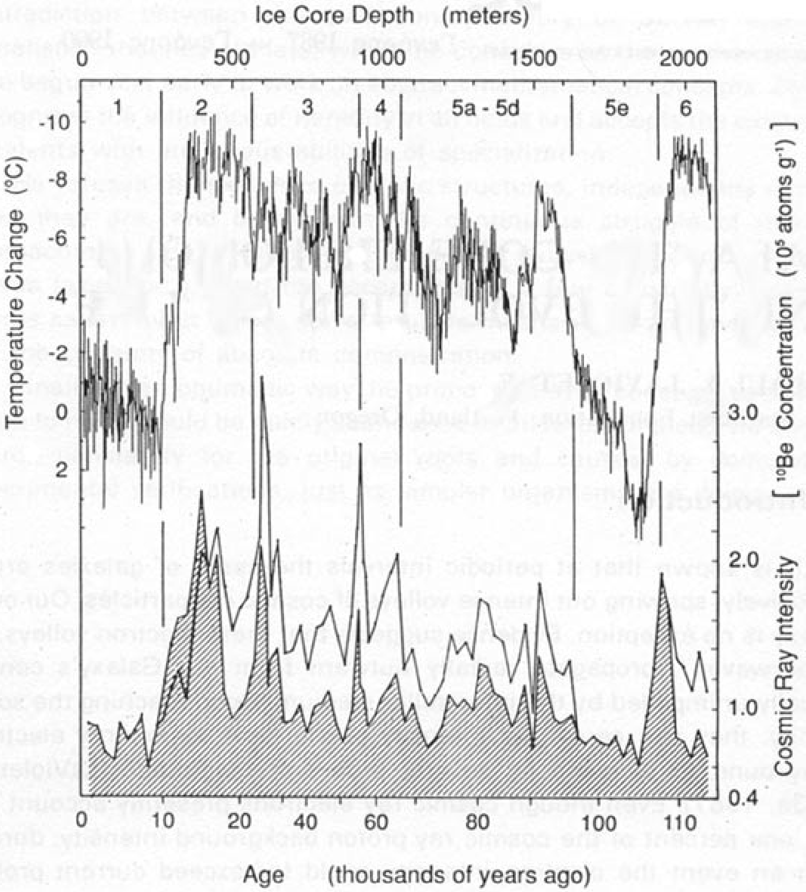

Figure 1. Variations of cosmic ray intensity in the Earth's vicinity registered in Vostok ice cover the past 10^5 years. Upper profile: Ice core deuterium/ hydrogen climatic profile (Jouzel et al., 1987). Bottom solid line: ^{10}Be concentration in the ice (Raisbeck et al., 1987). Lower shaded area: normalized ^{10}Be production rate (cosmic ray intensity) adjusted for variations in ice accumulation rate. Accumulation rates that are assumed are from Lorius et al. (1985), except for those from depths 260 - 465 m, which are based on correlations made between the isotope profile and radiocarbon dated climatic profiles.

an amount sufficient to cause a doubling of the human gene mutation rate. Even more intense increases of mutagenic radiation could have occurred at times prior to the beginning of this ^{10}Be record.

Cosmic dust propelled into the Solar System by the enhanced Galactic cosmic ray wind could affect the Earth's climate, either directly

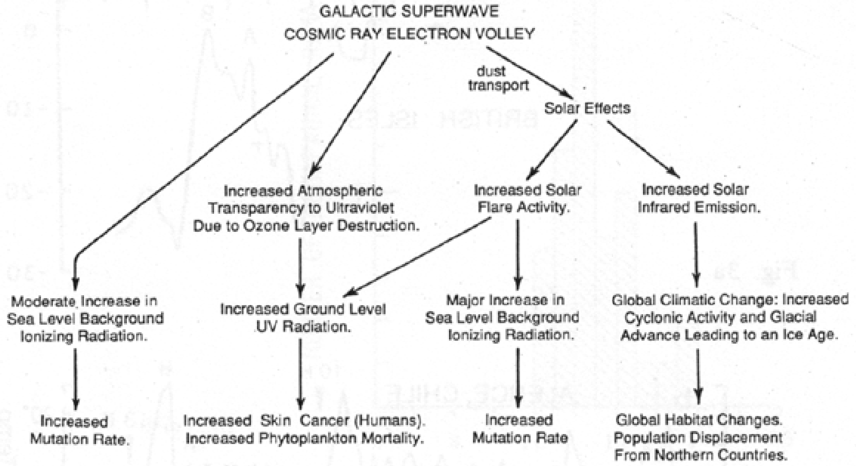

Figure 2. *Some of the ways in which a Galactic superwave could adversely affect living things.*

by altering the radiation transmission properties of the interstellar medium or indirectly by affecting the Sun's level of activity. The resulting abrupt changes of climate, as well as elevated levels of solar UV radiation, could pose a hazard to living things; (see Figure 2.) Interestingly a major megafaunal extinction episode occurred during the terminal cosmic ray event; (see Figure 3-d) (Meltzer and Mead, 1983). This coincided with an interval of abrupt climatic change (Figures 3-a & -b) which was accompanied by intense glacial meltwater flooding (Figure 3-c). Intense solar flares (Zook et al., 1977) and major geomagnetic disturbances (Nakajima et al., 1973; Clark and Kennett, 1973; Bucha, 1973; Morner, 1977, 1978) also occurred during this period.

One study has sparsely sampled the interval 18-60 kyrs BP with eight data points and has detected several times during this period when dust concentrations in the local interplanetary medium were hundreds of times present levels (LaViolette, 1983a, 1983b, 1985).* At present no data is available on Solar System cosmic dust concentrations prevailing during the terminal Pleistocene extinction episode. A study to obtain such data is urgently needed to help determine the connection between this extinction and the coincident cosmic ray event.

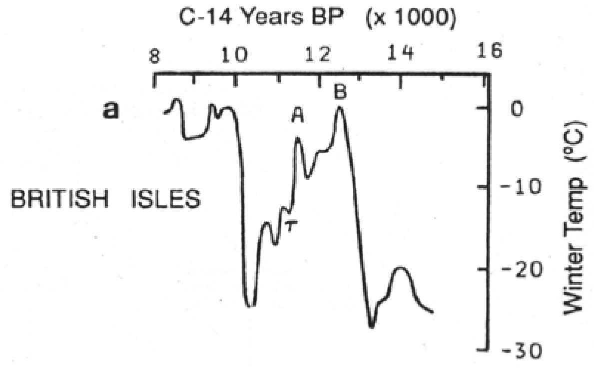

Fig. 3a

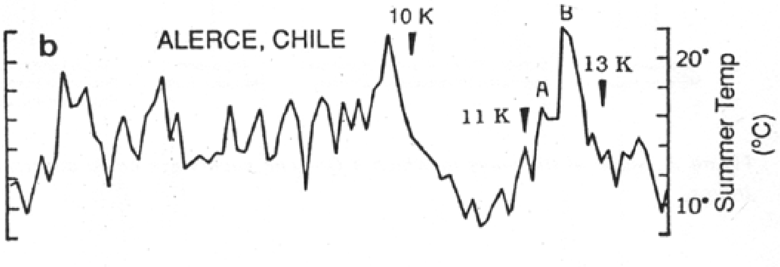

Fig. 3b

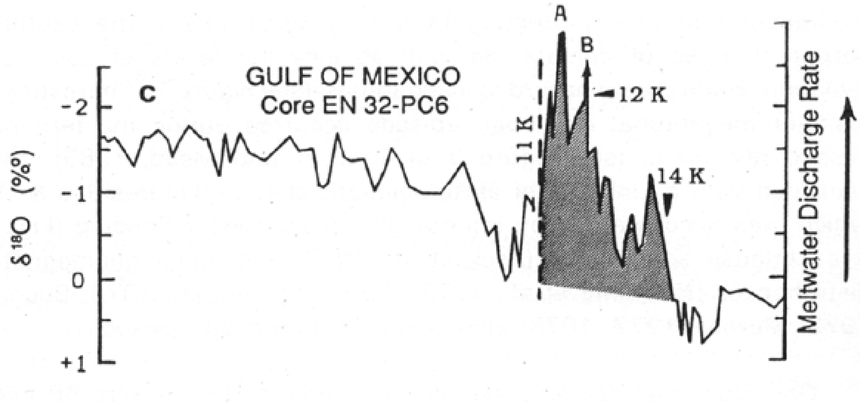

Fig. 3c

Figure 3. Paleotemperature profiles from (a) the Northern Hemisphere (Atkinson et al., 1987) and (b) Southern Hemisphere (Heusser & Streeter, 1980) are compared with (c) a profile charting freshwater discharge rate into the Gulf of Mexico (Leventer et al., 1983) and (d) the frequency of megafaunal extinctions in North America at the end of the Pleistocene, synthesized from the most reliable C-14 dates of the sample (Meltzer and Mead, 1983). The vertical arrow indicates the time of a major geomagnetic flip. Profiles (a) - (c) have been aligned so that their contours for the period 11 - 14.5 kyr BP match up with one another.

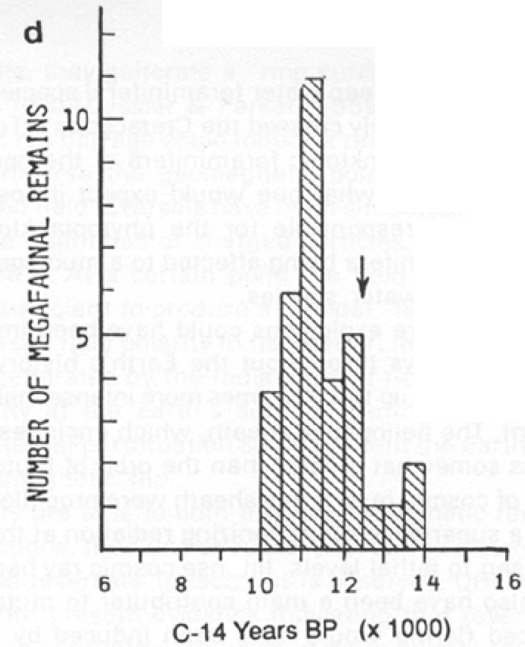

Fig. 3d

2. Cosmic Radiation as a Cause of Extinctions.

Loeblich and Tappan (1964) note that extinctions of phytoplankton observed periodically in the geologic record could not have been produced by local environmental changes. The short life span of plankton (as short as one week) coupled with their extreme abundance and rapid dispersal make it possible for them to quickly recolonize any localized region. Thus Loeblich and Tappan conclude that whatever caused the sudden extinction of entire groups of plankton, as for example occurred at the Cretaceous/Tertiary boundary, must have been due to a cause that was effective world-wide not merely to an accidental mutation in a single species. Moreover they point out that the rapid turn over and dispersal ability of foraminifera require that any such global effect, if mutagenic, must have occurred over a very short space of time.

Loeblich and Tappan suggest that these sudden extinctions were produced by momentary increases in the influx of cosmic radiation. Taking the terminal Cretaceous event as an example, they note that while

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* The dates which the author assigned to the eight samples in his earlier publications (LaViolette, 1983a, 1983b, 1985, 1987) must be revised. In view of ice core data that has more recently become available, the new sample age are given as: 18, 21.8, 24.3, 25.2, 26.9, 27.5, 35, 60 (kyrs BP). Also the ice core depths between 200 - 500 m in Figure 6 of LaViolette (1987) should be assigned older dates, e.g., 370 m = 13 kyrs BP.

two-thirds of the deep water foraminiferal species living along the continental shelves safely crossed the Cretaceous / Tertiary boundary, only a few species of planktonic foraminifera of the open ocean survived this transition. This is what one would expect if cosmic radiation was the primary agent responsible for the phytoplankton extinctions, surface dwelling foraminifera being affected to a much greater extent as compared with deep water species.

Galactic core explosions could have been important contributors of such cosmic rays throughout the Earth's history. Galactic superwaves could have been up to 1000 times more intense than the terminal Pleistocene event. The heliopause sheath, which encircles the Solar System with a radius somewhat greater than the orbit of Pluto could also be a major source of cosmic rays. If this sheath were propelled inward past the Earth during a superwave event, ionizing radiation at the Earth's surface could have risen to lethal levels. Intense cosmic ray barrages from solar flares could also have been a main contributor to mutagenic radiation levels. Enhanced flaring would have been induced by the Sun's accretion of cosmic dust brought into the Solar System by the superwave.

The discovery that marine extinction episodes exhibit a periodicity of 30 ± 1 million years which falls close to the Solar System's z-oscillation period of 33 ± 3 million years, the time required to travel above and below the Galactic plane, suggests that terrestrial evolution is shaped by Galactic factors (Rampino & Stothers, 1984; Schwartz & James, 1984). Dust captured from interstellar clouds at times when the Sun was crossing the Galactic plane would have aggravated the effects of superwaves. Large quantities of dust transported into the Solar System by passing superwaves would have adversely affected terrestrial climate as well as the Sun's level of flaring activity, thereby increasing the chance of faunal extinction (LaViolette, 1987).

Nearby supernova explosions could also have been responsible for some cosmic ray extinction events (Terry and Tucker, 1968). However, such explosions would have to be very close in order to produce radiation levels sufficient to cause faunal extinctions, placing their occurrence at only about once every 150 million years.

LaViolette (1983a, 1987) has suggested that intense cosmic ray volleys could trigger geomagnetic reversals. For example it is known that during solar storms solar flare particles become trapped in the Earth's radiation belts and produce a prolonged magnetic intensity decrease called "main phase decrease". Decreases of up to 1% of the Earth's total field intensity have been observed. As the trapped particles drift equatorially in the radiation belts, they generate a "ring current" magnetic field opposed to the Earth's field (Dessler & Parker, 1959). It is conceivable that a very large cosmic ray barrage could induce a ring current magnetic field large enough to reverse the geomagnetic polarity at the Earth's surface. Particle-induced field reversals have been simulated in the laboratory by injecting large quantities of charged particles into a magnetic field (Golden et al., 1981). At a certain point the field built up by the trapped ions becomes sufficient to produce a toroidal "field reversed ion ring" having a net reversed field polarity in its interior. In a similar fashion, the opposing field generated by the radiation belt ring current could reverse the field polarity at the Earth's surface. During a sufficiently prolonged event this external perturbation could reorient the Earth's core dynamo causing a geomagnetic flip.

If cosmic ray events are able to both trigger geomagnetic reversals and cause faunal extinctions, then one should expect to find a correlation between extinctions and reversals. In fact, this is observed. Uffen (1964) and Simpson (1965) both present evidence indicating that reversals of the Earth's magnetic field correlate with times of mass animal extinction and evolutionary spurts. Also, several studies have shown that there is a correlation between magnetic field reversals and the extinction of foraminifera and radiolaria (Harrison and Funnel, 1964; Opdyke et al., 1966; Hays and Opdyke, 1967; Hays et al., 1969; Hays, 1970 and 1971). Hays (1971) demonstrates that during the past 2.5 million years eight species of radiolaria became extinct and six of these eight species disappeared close to magnetic reversals. Although, he points out that agents other than cosmic radiation may be responsible for these extinctions; e.g., climatic change.

Pal and Creer (1986) find spurts in the frequency of geomagnetic reversals which occur at approximately 30 million year intervals, which is the same periodicity found for marine extinctions. As noted earlier, this correlates with the period of the Sun's oscillation above and below the Galactic plane. Excess dust accretion at such times could lead to excessive solar flaring which in turn could induce geomagnetic reversals.

Uffen (1963) has proposed that at times of geomagnetic reversals, when the Earth's field is at minimum strength, cosmic rays trapped in the radiation belts and solar wind particles could spill onto the Earth causing a major increase in the mutation rate of organisms. He suggests that these geomagnetic minima last several thousand years and arise as a result of instabilities in the Earth's liquid metal core dynamo, believed to generate the Earth's magnetic field.

However, Waddington (1967) argues that removal of the Earth's magnetic field sheath would have little effect on the evolution of organismes. Considering the effects that would be produced by the current cosmic ray background component, by periodic solar flares, and by possible dumping of the Earth's radiation belts, he concludes that removal of the Earth's magnetic shielding would increase the sea level radiation background by at most 16%. Arguing along the same lines, Harrision (1968) estimates that human beings living at sea level at the equator would experience only a 0.6% increase in their mutation rate if the Earth's protective magnetic sheath were removed. For mammals with shorter life spans the increase would be even less.

The objections raised against Uffen's cosmic ray hypothesis may be avoided simply by admitting the possibility that the cosmic ray background becomes substantially enhanced during magnetic field reversals. Then, it is no longer necessary to invoke a independent means for generating field reversals - the cosmic ray-blasts would serve both as the cause of the reversals and as the agents of extinction. Moreover the Earth's magnetic field need no longer be regarded as the cause of extinctions; rather, it merely serves as a marker indicating the time when these Galactic-solar cosmic ray events took place.

3. Choosing Among Alternatives: Cosmic Bodies or Cosmic Rays?

Urey (1957, 1962, 1963, 1973) proposed that the fields of tektites (meteoritic debris) found in the Earth's sediments were produced by periodic collisions with passing comets, and that these collisions terminated geological periods. This idea gained in popularity following the discovery by the Berkeley group (Alvarez et al., 1980) of elevated concentrations of iridium at the Cretaceous/Tertiary boundary, which marks the extinction of the dinosaurs.*

More recently, researchers have searched for iridium spikes at the boundaries of geologic period dating back as far as 600 million years (Orth and Attrep, 1988; Kyte, 1988). Although some iridium anomalies have been found, there is no evidence that these were produced by asteroid or comet impacts. So the Cretaceous / Tertiary cosmic event appears

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* Since Ir is about 10.000 times more abundant in meteoritic and cometary material as compared with terrestrial crustal rock, it serves as a good indicator of the influx of extraterrestrial material.

to be relatively unique. Two or three impact events occurred during the late Eocene leaving behind fields of strewn microtektites and cosmic spherules (Glass, 1988). However, neither of these events is associated with an unusual number of extinctions. It appears then that there are few mass extinction events in the geologic record which can be attributed to collisions with comets or asteroids.

Glass and Heezen (1967) report evidence of a microtektite strewn field in Indian Ocean sediments which are contemporaneous with the Brunhes/Matuyama geomagnetic reversal (~ 700 kyrs BP). They note that this event also coincides with changes in fossil plankton and with the extinction of Java man. The cosmic debris, which is strewn over an area 10,000 by 7,000 km in extent, amounts to a total mass of around 2.5×10^{15} grams, capable of constituting a meteoric body 1 kilometer in diameter.

Noting that another microtektite field situated off the Ivory Coast (~ 1.2 million years BP) also coincides with a field reversal, Glass and Heezen conclude that cosmic encounters might somehow cause these reversals by disturbing the Earth's magnetohydrodynamic dynamo. More recently, Clube and Napier (1982), expanding on their idea, suggest that collisions with bodies as small as 10^{13} grams ($E \sim 1000$ tons of TNT) could cause a disturbance to the core dynamo sufficient to induce a field reversal. However, since there is no observational evidence to support this claim and since little is known about the operation of the Earth's core dynamo or its degree of stability, the suggestion of a causal connection between planetesimal impacts and geomagnetic reversals should be regarded with some reservation. The earlier suggestion that reversals are produced by cosmic ray bombardment events seems a more plausible alternative.

One way of testing the cosmic ray hypothesis is to determine whether ^{10}Be concentration increases at a reversal boundary. A study of ^{10}Be concentration across the Brunhes/Matuyama boundary shows that ^{10}Be production rate did increase at the time of the reversal; (see Figure 4) (Raisbeck, et al., 1985). Given a sedimentation rate of 2.5 cm/kyr, this cosmic ray event spans a period of about 12 - 16 thousand years.

The question that remains is whether this ^{10}Be increase was due to a real increace in the primary cosmic ray flux, or was part or all of it due to decreased geomagnetic shielding brought about by a temporary reduction of the geomagnetic field intensity. Observations of ^{10}Be production rate in Greenland (77° N, 82° W) (Beer et al., 1984) and Antarctica (74° S, 124° E) (Raisbeck et al., 1981) indicate that that production rate during

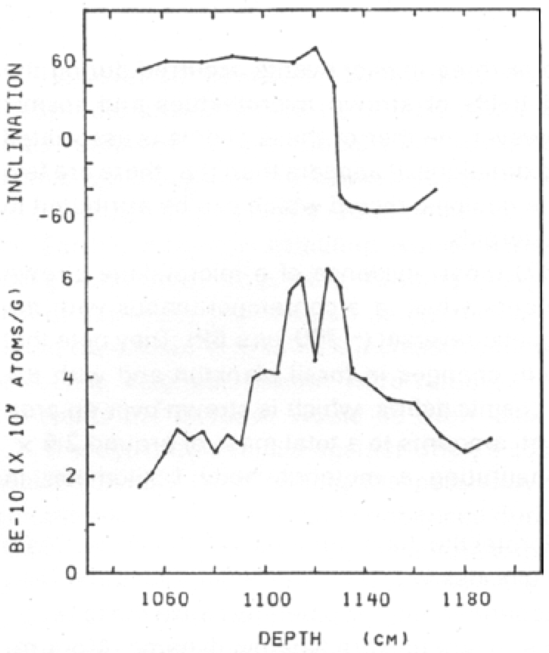

Figure 4. Increased beryllium-10 production at the Brunhes/ Matuyama geomagnetic boundary in ocean core V 16-58. Upper profile: magnetic inclination; Lower profile: ^{10}*Be concentration.*

the past 6000 years has been constant despite a gradual two-fold increase in geomagnetic field intensity. The data for the Brunhes/ Matuyama boundary, however, comes from a core located at a lower latitude (46°S, 31°E) where geomagnetic screening could be more important. To more definitively test whether a cosmic ray event triggered the Brunhes / Matuyama reversal, ^{10}Be data should be taken from a core located closer to the poles where screening factor would be minimal.

If the ^{10}Be peak at this reversal charts a real increase in the ambient cosmic ray flux, then it is reasonable to infer that an astronomical event such as a Galactic superwave may have contributed to the extinction of Java man. The same cosmic ray event may have been instrumental in shaping the evolution of Petralonian man in northern Greece (Poulianos, 1982), whose remains date from a time that immediately precedes this geomagnetic flip.

4. Quantum Speciation.

If Galactic cosmic ray volleys are a primary factor shaping the evolution of life, then evolution should be found to occur in spurts, rather than in a gradual fashion. This is found to be the case. There is considerable evidence to indicate that evolution proceeds forward in a step-like manner with the majority of change in a species occurring at periodic intervals over a very short space of time. Most of the evolution is concentrated within a small germinal population which may involve fewer than 10 individuals and the spurt may occur in a space of time spanning only a few generations. This phenomenon, which has come to be called "quantum speciation" (Grant, 1963), was first explored by Ernst Mayr (1942, 1954, 1963).

Often these evolutionary quantum jumps occur at times when the parent species becomes decimated. Such circumstance, whereby a population is destroyed leaving one or more localized genotypically distinctive populations, has been termed *catastrophic selection* (Lewis, 1962, 1966). Catastrophic selection is difficult to explain in terms of the Darwinian theory of natural selection since the latter suggests that major evolutionary changes should occur at times when the forces of competition and survival of the fittest are particularly acute, i.e., during times of overpopulation.

The concepts of quantum speciation and catastrophic selection follow as a natural consequence of the superwave hypothesis. The elevation of background radiation fluxes to lethal levels could simultaneously decimate populations, segregate species, and accelerate mutation. This would take place over a wide geographical area and would act relatively indiscriminately over a wide variety of unrelated species occupying distinctly different ecological niches.

Such cosmic ray events could account for the phenomenon of *adaptive radiation*, the rapid proliferation of new taxa from a single ancestral group. The branching points in Figure 5 illustrate this phenomenon. As is seen here, each extinction episode is immediately followed by an evolutionary burst in which many new kinds of organisms suddenly make their appearance. Most evolutionary change occurs during adaptive radiation, a phenomenon which takes place preferentially in regions having ecological conditions that favor diversification, that is, in isolated regions where competition and predation are unusually weak (Simpson, 1944, 1953; Stanley, 1979). This concept is particularly useful when considering the dynamics of evolution where mass extinction plays a dominant role, since extinction creates vacant ecologic islands that may be subsequently colonized by new species. One good example is the extinction of the dinosaurs at the end of the Cretaceous period, an episode that was immediately followed by a 25 million year period in which the number of mammalian families increased by about six fold.

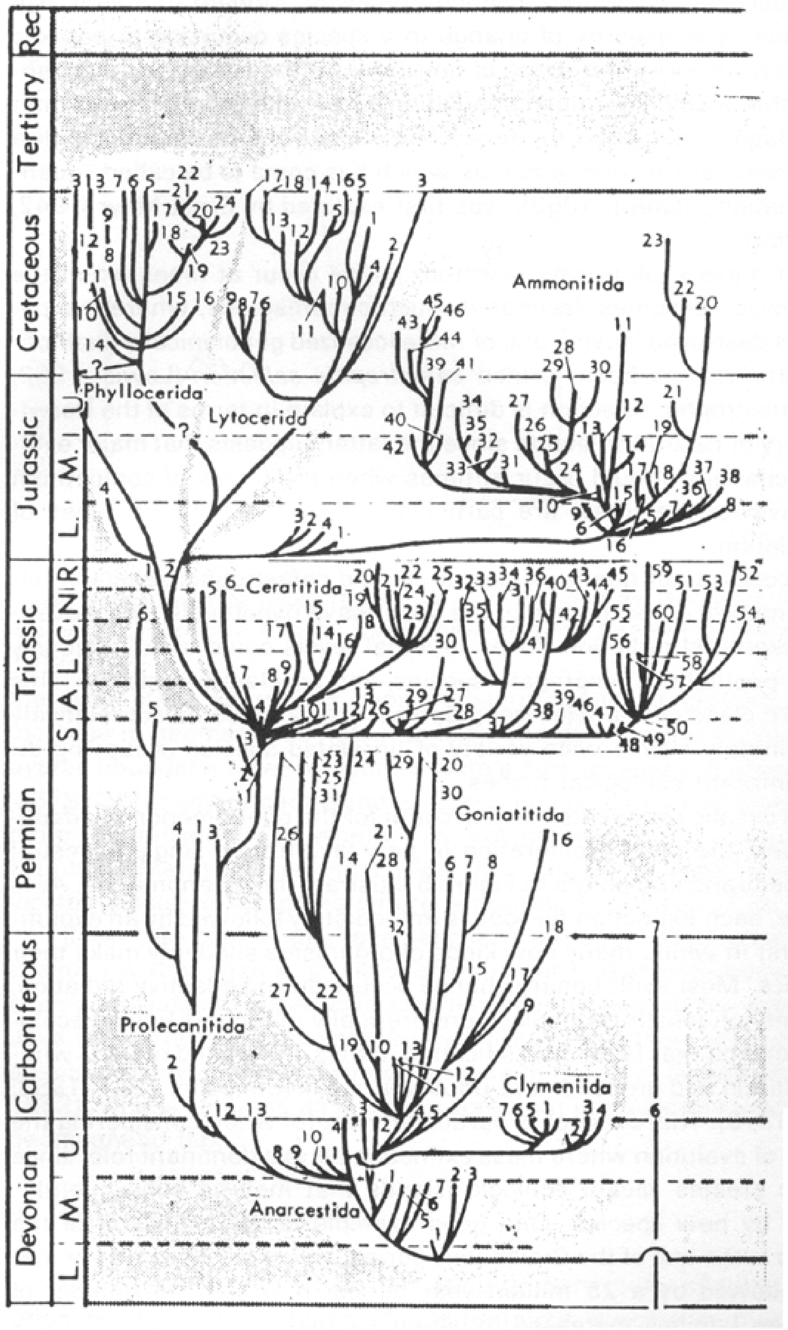

Figure 5. Phylogeny of the order of Ammonoida showing the rapid appearance of new families following events of mass extinction (Teichert, 1967).

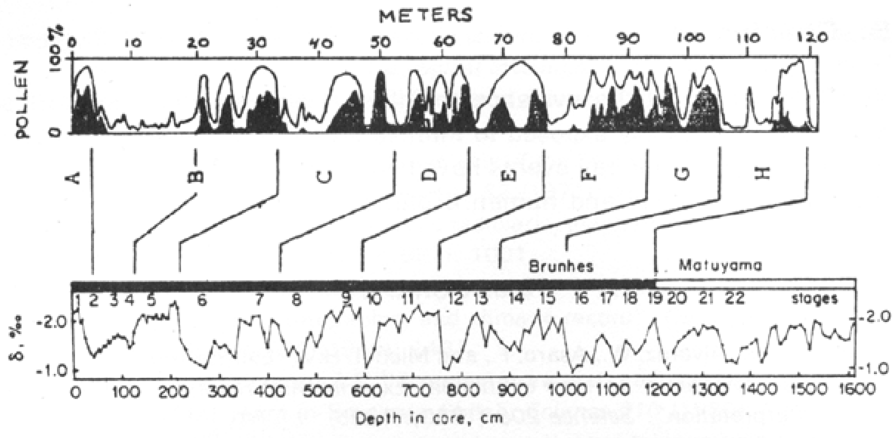

Figure E-1. (upper profile) Pollen diagram for the 120 meter Philippi peat bog core from eastern Macedonia (after Wijmstra, 1975). Lower percentage indicates a cooler climate. (lower profile) Oxygen isotope variations for core = V 28-238 from the equatorial Pacific (Shackleton and Opdyke, 1973). Less negative values indicate a cooler climate (greater ice volume). The upper horizontal scale indicates standard isotope stages along with corresponding magnetic polarity epochs (black= normal, white= reversed).

If cosmic radiation periodically has a major effect on life forms, then the rate of extinction and speciation for a given species should be found to be positively correlated. In fact, the rate of speciation in adaptive radiation and the rate of extinction are found to be strongly correlated in the animal world. For example, species with high average duration, i.e., a low rate of extinction, E, also have low net rates of speciation, R, the *net* rate of speciation being the difference between the speciation rate and the extinction rate; i.e.S — E.

A second related finding is that, as the rate of extinction increases across a spectrum of taxa, the rate of speciation in adaptive radiation also tends to increase proportionately (Stanley, 1979, p. 259). Thus if E for a species is twice as large, its S (and R) will also be twice as large.

If cosmic ray events play a major role in evolution, then the rate of speciation of a given species should depend on its relative degree of vulnerability to radiation exposure. In fact, land taxa, which are more vulnerable to exposure to cosmic radiation, are found to speciate much more rapidly than marine taxa (Stanley, 1979, p. 231). However, one must somehow explain why certain sea creatures such as Graptoloids, Ammonites, and Trilobites, all now extinct, rank among the highest in R and E values. Perhaps this discrepancy could be accounted for if these particular marine species spent part or in some cases all of their life cycle either close to the ocean surface or in shallow water.

5. Conclusion.

Considering all the evidence together, it appears that the Earth's surface is periodically exposed to intense levels of mutagenic radiation and that such cosmic ray events have been instrumental in accelerating the rate of biological and human evolution on our planet.

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ΠΕΡΙΛΗΨΗ

ΟΙ ΕΚΡΗΞΕΙΣ ΤΟΥ ΓΑΛΑΞΙΑΚΟΥ ΠΥΡΗΝΑ ΚΑΙ Η ΕΞΕΛΙΞΗ ΤΗΣ ΖΩΗΣ

Του Δρα PAUL A. LAVIOLETTE

Ο Δρ. Πωλ Λαβιολέτ, που είναι και μέλος της Ανθρωπολογικής Εταιρείας Ελλάδος, παρουσιάζει στον ΑΝΘΡΩΠΟ τις απόψεις του σχετικά με την εξέλιξη της ζωής σε σχέση με τις εκρήξεις στο Γαλαξιακό Σύστημα.