years' time. He did not want to suggest that the full turbine or compressor should be handled by DNS, but there were various bits of the system that in his view should be, keeping always the designer's needs in mind.

He referred to questions often raised about the possible relevance of stability theory in turbomachinery. At first sight stability would seem unlikely to be a major consideration because of the high disturbance environment, but various presentations made at the meeting showed that such a conclusion might be hasty. Reshotko's work on algebraic growth showed the importance of analysing transient disturbances. There was still the unresolved question about why e^n methods do not work as well on blades as on wings; Herbert had suggested several reasons that need to be investigated. Narasimha saw further use for the simpler alternatives that he and his colleagues at Bangalore had investigated. Questions of global and convective instability may play an important role in achieving a fuller understanding of the behaviour of separation bubbles and of near wakes, as Frank Smith had suggested.

Narasimha finally listed what appeared to him to be conspicuous gaps in the present research scene. There is first of all too little work on three-dimensional flows, too little DNS/LES (done specifically for turbomachinery flows), and too little theory. A coordinated project on a given blade row as more and more stages are mounted upstream – coordinating between experiments and computation, if not theory – seemed to him to be a great need. Along the line of the suggestions made by Ashpis, international programmes on the disturbance environment in turbomachinery and on DNS/LES would seem highly worthwhile; ERCOFTAC and Minnowbrook have shown how such international programmes can be organized. With the funding situation becoming so difficult, there seemed to be no alternative.

He concluded by thanking the organizers for putting together again such an interesting and pleasant meeting where industry, academics and government were all so well represented and interacted with such enthusiasm and frankness.

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RESEARCH NEWS

Forces of life and death

N. Bhandari

It appears increasingly likely that the origin of life on Earth, and its evolution, to a significant extent, may be governed by processes operating from beyond the Earth. The origin of life on Earth has long been postulated to have been initiated from organic molecules accreted from space, through influx of meteorites and micrometerorites. Some molecules which may be precursors of life have been identified in meteorites and the recent findings[1] of laevorotatory (left handed) amino acids in the carbonaceous meteorite which fell in Murchison, Australia in 1969, having the same handedness as the amino acids occurring on Earth (and not a racemic mixture, i.e. left and right handed in equal abundance as expected in chemical synthesis) strengthens this idea. Presence of left handed amino acids in Murchison had earlier been suspected to be contamination from the Earth itself but these authors measured the istotopic ratio of nitrogen, ^{15}N/^{14}N, in these amino acids and found that ^{15}N is heavily enriched, having isotopic composition (defined by δ 15N = +37 to +184‰) different from that found in organic matter on the Earth (–10 to +20‰), thus ruling out their terrestrial origin. Although, concrete experimental evidence for processes responsible for the origin of life on Earth is hard to obtain, the subsequent mass extinctions which occurred later on Earth (Figure 1) since the Cambrian (the past 570 million years) and the increase in biodiversity, which followed the catastrophe every time, bear some support to the extraterrestrial influence on drastic changes in history of life on Earth.

The two most recent mass extinctions, the first, a series of minor events, around 33.7 ± 0.5 million years ago, when the Earth changed from Eocene to Oligocene epoch and the other, more severe one, around 65 million years ago when the Earth changed from Cretaceous to Palaeocene epoch have been studied in detail in recent years. Impact of large bodies from space on the Earth throughout its geologic history is an established fact but Bottomley *et al.*[2] have carefully dated the Popigai impact crater in Siberia (100 km diameter) and come to the conclusion that its age lies too close (within a few hundred thousand years) to the Chesapeake Bay crater (85 km diameter), off the Coast of Virginia in USA, which is dated at 35.3 ± 0.2 million years and therefore the two impacts occurred almost simultaneously. Such a quick succession of impacts is not expected from any statistical consideration from the known orbital populations of comets or asteroids. Only a large number of comets, if deflected from the Oort's cloud belt by some gravitational perturbations, can give rise to such a comet shower, resulting in multiple impacts over a short period of time. The motion of the Sun through the galaxy across the spiral arms due to its differential orbital period and its vertical motion, up and down the galactic plane, can also result in changes in influx rate of extra solar system matter, which can give rise to enhanced impact rates of meteorites and micrometeorites on Earth. Such impacts have to be periodic but this periodicity has not been definitely established from the crater ages. Serious efforts are required to find physical and chemical evidences of such material at geological boundaries to confirm these hypotheses.

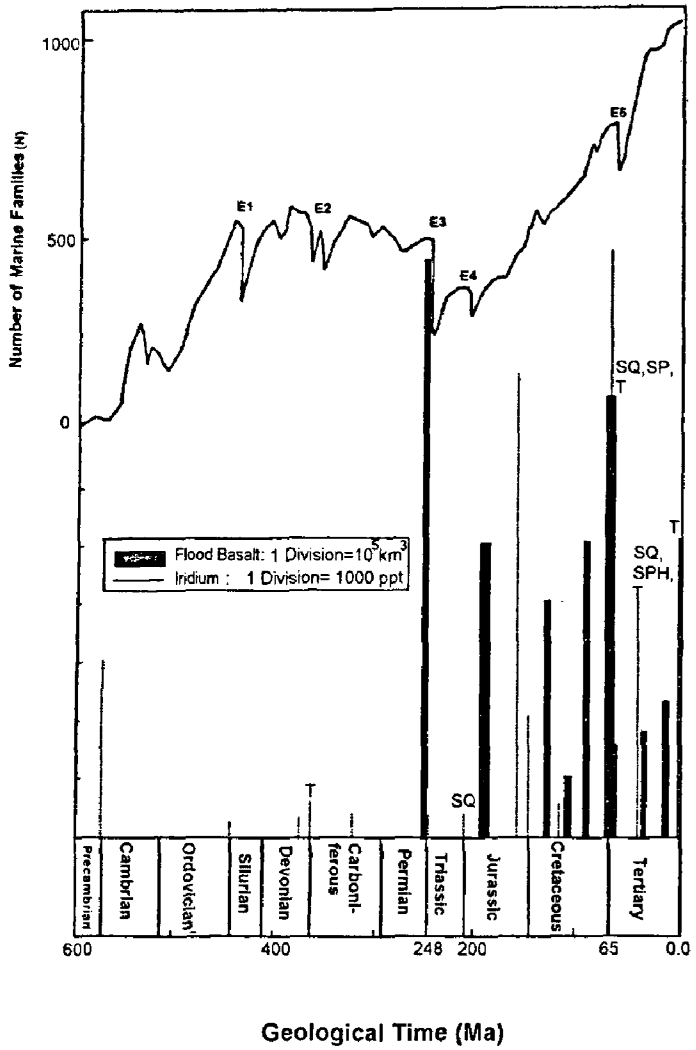

Figure 1. Sepkoski's biodiversity curve for marine families during the Phanerozoic. E1 to E5 represent major mass extinction events. Timing of major volcanic events on Earth and presence of impact signatures like iridium, shocked quartz (SQ), Nickel-rich spinels (SP) and spherules (SPH), some of which coincide with the extinctions are shown[4].

The mid to Terminal Eocene is considered to be an eventful time with several minor events of faunal and floral extinctions beginning at 40 Ma, punctuated by a few impacts, though not always accompanied by extinction, and a large-scale volcanism in Ethiopia, culminating in a large sea level drop and major ice advance. Enahncement of concentration of iridium, an element high in meteorites and low in Earth's crust, at one or possibly two horizons in deep sea sediments, deposited around that time, and the occurrence of microtektites just above them further confirm the multiplicity of impacts. Moreover, the peak activity of Ethiopian volcanism, which was a serious contender for the cause of mass extinction 34 million years ago, has turned out to be much younger, now carefully dated by Corine Hofmann and colleagues[3] at 30 ± 1 million years. The extinction events between Mid-Eocene to the Terminal Eocene, may have been caused by change in sea levels or sudden cooling of climate but the physical cause which initiated such severe climatic variations remains elusive.

Both the hypotheses, impact and volcanism, because of large time gaps separating them from mass extinctions, could not provide a plausible cause of the mass extinctions during the Mid Eocene–Oligocene period. A number of other extraterrestrial causes such as supernovae explosions or collisions of neutron stars in the vicinity of Earth or bursts of neutrinos and consequent radiation overdose directly by neutron- and muon-induced transmutations or via destruction of ozone layer through lethal solar ultraviolet dose, disruption of food chain, or cell mutations have been proposed. More exotic mechanisms involving dark matter accumulation on the Earth, etc. have also been postulated.

At the Terminal Cretaceous, the impact event, very likely of a cometary bolide[4], is well established and the 200–300 km crater at Chicxulub, in Gulf of Mexico is, beyond doubt, of impact origin. Simultaneity of this impact with the terminal mass extinction event 65 million years ago suggests a cause and effect relationship. Again, according to precise dating of lava flows by Venkatesan and Pande[5], Deccan volcanism, a serious contender for mass extinction at Cretaceous–Tertiary boundary seems to have peaked 2 million years before the biological crisis, too early to have a cause and effect relationship with mass extinction. Thus, at the Cretaceous–Tertiary boundary, it is clear that volcanism may have created some stress on life but the extinction or at least the 'last nail in the coffin' was accomplished by a bolide impact.

Though extinction can be caused by one or more of the mechanisms proposed, what is of interest for evolution of life is that after every such catastrophe, the biodiversity increased significantly (Figure 1). The forces of survival became so strong that whosoever escaped the catastrophic event diversified with redoubled vigour. This may have been accomplished by a close interaction with the environment which changed significantly due to the catastrophic events. So the catastrophe, in effect, served as a blessing in disguise, giving rise to new life forms and special capabilities to survive under duress.

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