Perilous Planet Earth Revisited

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Introduction

Fifteen years have passed since my book, *Perilous Planet Earth: Catastrophes and Catastrophism through the Ages*, was published by Cambridge University Press, so, although it's still in print, 2018 seems an appropriate time to reflect on relevant developments since the time of its publication. However, first let me tell how, had I not become a member of the SIS, this book would never have been written. During the 1970s, I'd read Immanuel Velikovsky's *Worlds in Collision* [1] and Alfred de Grazia's *The Velikovsky Affair* [2], which convinced me that the Earth had suffered major catastrophes in the past and, although (whilst retaining an open mind) I was unconvinced about Velikovsky's proposed mechanism involving wandering planets, it seemed clear that unfair attempts had been made to suppress his arguments. Furthermore, Velikovsky had made predictions which proved to be correct, so his ideas deserved serious considerations. In 1979, I read Francis Hitching's fascinating *World Atlas of Mysteries* [3] and saw, after the references to the section on Velikovsky's predictions, the following statement: "Further references, supporting statements and discussion are obtainable from the Society for Interdisciplinary Studies", a contact address in Manchester being provided. Hitching, in his acknowledgements, thanked: "Peter James, associate editor of the *Journal* of the Society for Inter-Disciplinary Studies, whose research effort has been prodigious … He has known about the *Atlas* almost since its conception, and through long hours of discussion has helped crucially in formulating the approach to many of the contentious issues that are covered." Fired with enthusiasm, I wrote at once to the address in Manchester and received a hand-written reply (which I still have) dated 11 December 1979 from Ralph Amelan, who was then the SIS Secretary. In consequence, I became a member for the forthcoming year, and have been one ever since.

Hitherto, I'd been reading books by and about Velikovsky in isolation, so my primary reason for joining the SIS (which, at that time was presenting itself as "An International Forum for the Velikovsky Debate") was to be brought up-to-date with developments. The situation proved to be more complex than I'd expected. As noted in a first-hand account provided in 1984 by de Grazia in *Cosmic Heretics*, the Velikovskian movement had begun to fragment about ten years earlier [4]. A significant event which brought matters to a head was a well-attended symposium held in San Francisco in 1974, under the auspices of the American Association for the Advancement of Science, in which several prominent scientists (particularly astronomer Carl Sagan) debated Velikovsky's theories with their originator and some of his chosen colleagues [5].

After the end of this symposium, there was widespread acknowledgement that Sagan had used unfair tactics and made several errors. Nevertheless, a strong consensus emerged amongst scientists, even ones sympathetic to some aspects of Velikovsky's ideas, that his scenario of planetary catastrophism had now been given appropriate consideration and found to be unsustainable. It would be going too far to say that Velikovskian planetary catastrophism was an impossibility (because very few theories can be deemed *impossible*) but, on the basis of the evidence now available, his scenario seemed highly improbable. By this time, some more of Velikovsky's predictions had been fulfilled, but others had been found to be wrong, and even those which had turned out to be correct were of low discriminatory value, i.e. they could also be satisfied by other alternatives to the theories currently in vogue. In overall terms, Velikovsky had incorporated a range of theories into his complex scenario, so the fact that some of them were subsequently shown to be incorrect did not automatically mean that the rest should be discarded, but similarly there was no valid reason for thinking that, because some of them turned out to be consistent with new evidence, the entire scenario must necessarily be valid. As for Velikovsky's supporters, some took Sagan's unfairness as justification for keeping their original beliefs intact, whereas others began to consider the possibility that there might have been substance in at least some of the difficulties expressed [6].

According to de Grazia, "The effective scientific criticism of Velikovsky came from those who were sympathetic to his work" [7]. In similar vein, David Talbott wrote, "It is now clear that Velikovsky was not correct on many details, but his best critics are those who have devoted their lives to investigating questions and possibilities arising from his work" [8].

Modifications to Velikovsky's scheme began to be suggested, to eliminate aspects that seemed problematical, and eventually this led to the creation of alternative catastrophist models, arising out of Velikovsky's original ideas. Writing in 1984, de Grazia identified three major models which had been formulated by people he regarded as "Cosmic Heretics", i.e. ones who went against the prevailing uniformitarian paradigm which dominated conventional scholarship, and accepted the key position specified in the Preface to Velikovsky's *Worlds in Collision*, that there had been global catastrophes in historical times, caused by extraterrestrial agents [9]. The first was the Saturn Theory,

developed by Dwardu Cardona and then David Talbott (followed by Ev Cochrane) from Velikovsky's idea that the Earth had once been a satellite of Saturn [10]. The second, developed by de Grazia in collaboration with Earl Milton, was the Solaria Binaria model, which envisaged an even earlier stage in the development of the Solar System, when the Sun was part of a binary system with Super-Uranus [11]. These models, like that of Velikovsky, were devised largely on the basis of accounts in ancient myths of the activities of gods and goddesses associated with planets, and it was acknowledged that a proper scientific justification for them had yet to be formulated [12]. Also, since human beings living on Earth must have observed the events which gave rise to myths, a plausible explanation was required as to how they could have remained alive through major changes of the Earth's orbit. Peter James commented that "there are immense problems with the Saturnists' theory. They have barely begun to tackle even the most obvious of these. How could the Earth – and its inhabitants – possibly have survived the upheaval of being wrenched from its position as a satellite of Saturn and hurled into an orbit around the Sun?" [13]

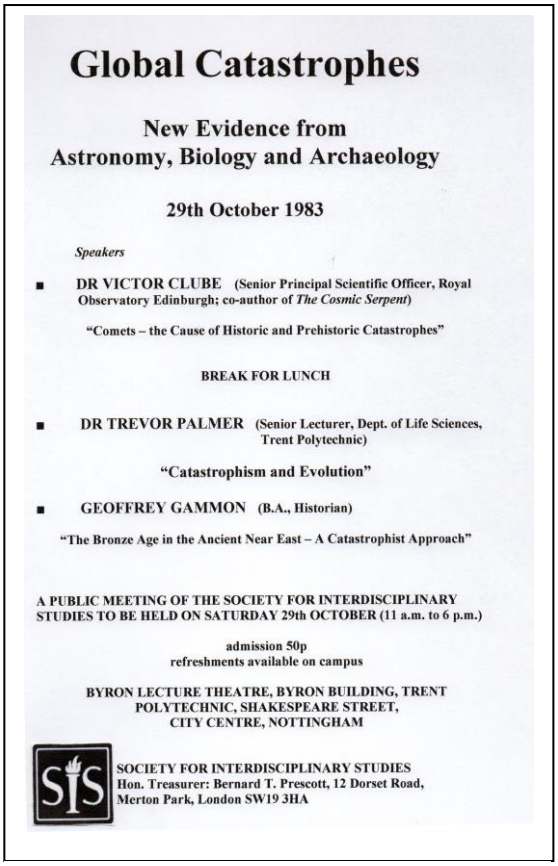
The third of the major models proposed by "Cosmic Heretics" took a diametrically-opposite approach, giving priority to maintaining compatibility with physical evidence and established scientific laws. In their 1982 book, *The Cosmic Serpent*, British astronomers Victor Clube and Bill Napier argued that global catastrophes had repeatedly occurred in historical times when the Earth passed through a large cloud of dust and rocks resulting from the disintegration of a particularly large comet. Remnants of this cloud can be seen today in the complex which includes the Taurid meteor stream and comet Encke. During passages through this cloud when it was much denser than it is today, the Earth would have been shielded from the Sun's heat and light by the dust and would have experienced frequent impact from extraterrestrial objects. The association of catastrophes on Earth with brilliant cometary fragments in the sky could have given rise to various myths and then, as the bright comets dimmed due to further fragmentation, myths linked to them might have been transferred to planets which were then in the same parts of the sky [14]. However, many researchers were unconvinced by arguments that myths associated with planetary deities owed their origin to cometary phenomena [15].

This, then, was the situation during the first few years of my SIS membership. The "Velikovsky Debate" taking place was not so much one between Velikovskian catastrophists and conventional uniformitarians, as ones between supporters of different catastrophist models, the specific scenario proposed by Velikovsky being just one of these. Most of the participants would have regarded themselves as Velikovskians, and sometimes a revised scenario simply included a detail which was a refinement of Velikovsky's original model, as with Peter Warlow's "tippe top" concept, presented to SIS members in 1980. Nevertheless, as de Grazia reported, Warlow's theory proved highly-controversial amongst his fellow-Velikovskians [16]. To broaden the debate, Victor Clube, a Cosmic Heretic but perhaps not a Velikovskian, was invited to discuss Velikovsky's ideas and his own in an address to an SIS meeting in London in June 1982 [17], shortly before the publication of *The Cosmic Serpent*.

The Development of Perilous Planet Earth

When joining the SIS at the end of 1979, I never imagined that I, as a clinical biochemist, would ever have anything to contribute to discussions about chronology or catastrophism. However, at almost exactly the same time, in America, Luis Alvarez and his son, Walter, produced evidence of high iridium levels at the Cretaceous-Tertiary boundary at sites throughout the world, which they argued was evidence that the extinction of the dinosaurs and many other species at this time (dated by geologists to 65 million years ago [18]), had been caused by the impact of a large asteroid or comet. Iridium, normally found in only small amounts in the Earth's crust, was known to be present in much larger amounts in extraterrestrial objects. As interest in this theory continued to grow, Brian Moore and Peter James, both of them editors of *Review* during this period, encouraged me to research and report to SIS members on developments in prehistoric catastrophism. In fact, that was a logical development for me, because my specialist research subject was the study of inherited disorders. I was used to investigating the terrible consequences of genetic mutations, yet, according to the Modern Synthesis of Darwinism, evolution was driven by the advantageous effects of some genetic mutations, operating in a gradual fashion within populations. It would be interesting to examine the other side of the coin, and form a judgement about whether significant evolutionary changes could really be brought about in a gradual fashion, as supposed by conventional Darwinians. It soon seemed to me that some of the key steps in evolution, including the replacement of the dinosaurs by the mammals as the dominant group of land animals, required the involvement of catastrophist mechanisms.

With controversies about the extinction of the dinosaurs still receiving considerable media attention, Brian Moore, at that time Chairman of the SIS as well as an editor of *Review*, invited me to present a talk at an SIS meeting in Nottingham in the autumn of 1983. The other speakers at this meeting, entitled *Global Catastrophes: New Evidence from Astronomy, Biology and Archaeology*, were Victor Clube and Geoffrey Gammon (Fig.1). I chose the title, "Catastrophism and Evolution" for my talk, taking this from a section-heading in Velikovsky's *Earth in Upheaval*. Such was the general interest in this meeting that I was interviewed live on BBC Radio Nottingham on the day before it took place, and the talks were presented to a packed audience in one of the largest lecture theatres in Nottingham [19].



Global Catastrophes

New Evidence from Astronomy, Biology and Archaeology

29th October 1983

Speakers

- **DR VICTOR CLUBE** (Senior Principal Scientific Officer, Royal Observatory Edinburgh; co-author of *The Cosmic Serpent*)

"Comets – the Cause of Historic and Prehistoric Catastrophes"

BREAK FOR LUNCH

- **DR TREVOR PALMER** (Senior Lecturer, Dept. of Life Sciences, Trent Polytechnic)

"Catastrophism and Evolution"

- **GEOFFREY GAMMON** (B.A., Historian)

"The Bronze Age in the Ancient Near East – A Catastrophist Approach"

A PUBLIC MEETING OF THE SOCIETY FOR INTERDISCIPLINARY STUDIES TO BE HELD ON SATURDAY 29th OCTOBER (11 a.m. to 6 p.m.)

admission 50p
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Hon. Treasurer: Bernard T. Prescott, 12 Dorset Road, Merton Park, London SW19 3HA

Fig. 1. Poster for SIS Autumn Meeting, Nottingham, 1983.

Amongst those who attended was John Delin, science correspondent of the *Sunday Telegraph*, and he wrote a brief report which appeared in his newspaper on the following day.

The Spring 1984 meeting of the SIS, held in London, followed on from this, and was entitled, *Comets, Meteorites and Earth History*. The speakers were the Belgian scholar, René Gallant, described in *Review* as "a pioneer of modern catastrophism", and Professor Chandra Wickramasinghe, who had co-authored several controversial books with Fred Hoyle [20]. Gallant's major work, *Bombarded Earth*, was published in 1964. Several years earlier, he began corresponding with the eminent French archaeologist, Claude Schaeffer, who had found evidence that catastrophic destructions had occurred at sites throughout the Near East on several occasions during the Bronze Age. Gallant was also corresponding with Velikovsky, and he introduced him to Schaeffer. Both Gallant and Velikovsky associated Schaeffer's destruction-levels with cosmic catastrophism, but whereas Velikovsky believed they were evidence of planetary catastrophes, Gallant considered asteroid impacts to be a more likely cause [21].

An article based on my 1983 presentation about prehistoric catastrophes and their possible significance for the course of evolution was published in *Review* in 1985, and a brief update appeared in *Workshop* two years later [22]. Three more relevant articles were then published in *Review* in 1988, 1989 and 1990 [23]. All of this material was then brought together, with the incorporation of further developments, in a book entitled, *Catastrophism, Neocatastrophism and Evolution* (*CN&E*), edited by Bernard Newgrosh and published in 1994 by the SIS in association with Nottingham Trent University [24]. It was sent out to all SIS members, as a free supplement to their annual entitlement, in the year of publication. *CN&E* consisted of six chapters, the titles of the final three being the same as those of the articles published in *Review* in 1988-1990.

However, arguments continued to rage about the cause and timescale of the mass extinctions of species which had occurred, not only at the Cretaceous-Tertiary boundary, but also at the boundaries between some other geological periods, so I clearly had unfinished business. During the next few years, while I was working on an expanded and updated version of *CN&E*, I wrote two more articles arising from these studies, which subsequently appeared in *Review* [25]. The expanded book was published in New York in 1999 by Kluwer/Plenum. It was entitled, *Controversy*, with the sub-title*: Catastrophism and Evolution – The Ongoing Debate* [26]. Although *Controversy* was twice the size of *CN&E*, it retained the same chapter titles. Also, since it still focused on evolution, it said nothing about the Bronze Age destruction-layers found by Schaeffer, yet evidence relating to these was accumulating and becoming more refined.

In a major article published in *Review* in three parts (in 1983, 1987 and 1988), Moe Mandelkehr, an American engineer, cited archaeological, climatological and geological evidence to present an integrated model for a worldwide catastrophic event in 2300 BC [27]. At the first SIS Cambridge Conference in 1993, entitled *Evidence that the Earth has Suffered Catastrophes of Cosmic Origin in Historical Times*, both John Bimson and Bob Porter gave assessments of Schaeffer's findings in the light of subsequent developments, and each of them concluded that there was strong evidence of widespread catastrophic destructions of cities in the Near East towards the end of the Early Bronze Age, corresponding to the time of Mandelkehr's global event. However, the evidence for similar destructions at the end of the Middle Bronze Age, the time of Velikovsky's "Venus catastrophe", was more tenuous. Although there was some evidence of earthquake damage at many of the sites, there was nothing to indicate a cosmic event on the scale of that described by Velikovsky [28]. Developments with other forms of physical evidence had similarly provided little support for the concept of a "Venus catastrophe" during the second millennium BC. For example, although Velikovsky had suggested that the "Worzel Ash" discovered in 1959 had fallen from Venus and would be observed underlying all the Earth's oceans, it turned out that it was volcanic in origin and found in only a few locations [29].

At the 1993 Cambridge Conference, Bimson and Porter both concluded that it was far more likely that Bronze Age catastrophes had been caused by comets rather than planets [30]. A few years later, SIS Council accepted an offer from Benny Peiser, a Council member, to organise a second Cambridge Conference, which was held in 1997 and entitled

Natural Catastrophes during Bronze Age Civilsations: Archaeological, Geological, Astronomical and Cultural Perspectives. The energetic organisiser had recruited a large number of well-known guest speakers, and also ensured that the event was widely-publicised. The key-note address was given by Robert Matthews, the science correspondent of the *Sunday Telegraph*, and amongst the speakers were Clube, Napier and another British astronomer, Mark Bailey (Fig. 2), the last-mentioned also co-editing the Proceedings with Peiser and myself [31]. Afterwards, Peiser set up the electronic Cambridge Conference Network, so issues raised at the conference, as well as relevant new developments, could be discussed in detail.

Fig. 2. Bill Napier (left), Victor Clube (centre) and Mark Baillie at the Second SIS Cambridge Conference, 1997 (photo: Trevor Palmer).

During the conference, Peiser gave a comprehensive talk about the 2300 BC catastrophic event, and others presented evidence consistent with aspects of his presentation. The Belfast dendrochronologist, Mike Baillie, then went on to talk about regions of low tree-ring growth, indicating environmental downturns at 2345, 1628, 1159 and 207 BC, and also at AD 540, suggesting a possible cometary involvement in some of these events [32]. Two years later, Baillie gave an expanded and updated version of his presentation in *Exodus to Arthur: Catastrophic Encounters with Comets*, whilst, in the same year, Mandelkehr, in the first two of a series of eight more articles in *Review*, made it clear for the first time that he believed the overarching cause of the 2300 BC event was an encounter with cometary debris, as in the Clube-Napier scenario [33].

Also in 1999, David Keys, in *Catastrophe*, argued that the environmental crisis around AD 535 was caused by atmospheric dusting arising from a major eruption of Krakatoa. Baillie, in *From Exodus to Arthur*, accepted there were many reports of volcanic activity and also earthquakes at this time, but there were also many sightings of comets and meteors. Was the increased tectonic activity a consequence of a cosmic bombardment, as Clube and Napier suggested, or was the tectonic activity unrelated to the cosmic activity? Baillie commented that he had once been convinced it was the former, but now he was less sure [34].

In the autumn of the same year, at the request of David Salkeld, I presented, as the final paper of the SIS Silver Jubilee Conference, an investigation of events which might have given rise to the flood myths found all around the world. Not long afterwards, my son James, who was then a PhD student at Sheffield University (and is now Reader in Medieval History at St Andrews University) drew my attention to reports in Carolingian chronicles from the 9th century AD of civil wars taking place against a background of environmental hardships, earthquakes and frightening cosmic events. We went on to co-author an article published in *Review* 2002:1 which concluded that the evidence, taken as a whole, was consistent (if no more) with the Earth having been passing through a cloud of cometary debris, as in Clube and Napier's model, at this time [35]. Clube himself had been saying for some years prior to this that there was evidence of episodes of cosmic bombardment and also major environmental fluctuations (including the occurrence of a "Little Ice Age") throughout the AD period and, although the situation is now relatively calm, that may not last for much longer. The regular occurrence of cosmic bombardments, earthquakes, floods, famines and plagues no doubt helped sustain beliefs in end-of-the-world scenarios [36].

By this time I was already planning the book which became *Perilous Planet Earth*. Whereas *Controversy* had developed in straightforward fashion from *Catastrophism, Neocatastrophism and Evolution*, the new book would be fundamentally different from its predecessors, even though there would be much common ground between the three of them, all being concerned with the possible effects of catastrophes on the course of life on Earth. Despite that common theme, the first two had a joint-focus, catastrophism and evolution, whereas *Perilous Planet Earth* would focus specifically on catastrophism. In the first two books, "the course of life on Earth" effectively meant "the course of evolution (including human evolution)", whereas in the third it would also be taken to include "the course of human history". *Perilous Planet Earth* would include much new material, as well as relevant material from *Controversy*, re-written and re-positioned, whilst material relevant to evolution but not to catastrophism would be excluded. The finished book was in two parts, the first being entitled *Catastrophsim: The Story of its Decline and Fall ... and Resurrection*, and the second *Catastrophes and the History of Life on Earth*, there being 30 chapters altogether. *Perilous Planet Earth* was published in 2003 and dedicated "to the members of the Society for Interdisciplinary Studies and the Cambridge Conference Network" [37].

Catastrophism: The Story of Its Decline and Fall … And Resurrection

Decline and Fall

As documented in Part I of *Perilous Planet Earth (PPE)*, catastrophism had been the dominant geological paradigm in Europe throughout most of the first half of the 19th century [38]. Subsequently, it became generally supposed that the catastrophists of this period were poor scientists, who gave priority to their religious beliefs over objective evidence, but the true situation was much more complex than that. In France, the leading catastrophist, Georges Cuvier, who had risen to prominence as an outstanding anatomist, had little time for religion, except when he could quote scripture to gain popular support for his scientific theories. In Britain, there was more constraint on scientists, because the medieval philosophy of natural theology, which maintained that the primary purpose of science was to find evidence for the existence of a Creator, continued to be influential. Many of the prominent British scientists of the early 19th century were clergymen, because that was still a requirement for obtaining a senior post at either Oxford or Cambridge Universities. These clergymen-scientists usually took their religion very seriously but, when their scientific findings (and those of others) seemed incompatible with their religious beliefs, they didn't automatically reject the evidence. The geologist Adam Sedgwick, for example, was a very devout Christian, and he spent much of his career looking for evidence of the Universal Flood described in *Genesis*, but, in his address to the Geological Society in 1831, marking his retirement from office as its president, he announced that he'd previously been led astray by his expectations of what he would find, but he now accepted that it had been "incontestably established" that "the vast masses of diluvial gravel, scattered almost over the surface of the earth", had *not* been laid down in "one violent and transitory period" (*PPE* pp. 32-39).

More generally, the catastrophists were simply taking the evidence of the rocks at face-value, since it was clear that there were sharp breaks between rock-formations containing certain types of fossils and ones containing other types of fossils. That, after all, was the basis of the classification of geological periods, accepted by catastrophists and uniformitarians alike. Charles Lyell, the leading uniformitarian, argued in his *Principles of Geology* in the early 1830s that, because all the major changes currently taking place at the surface of the Earth were gradual in nature, then that must always have been the case, so the Earth must be far older than the clergymen-catastrophists supposed, on the basis of biblical dating, and, furthermore, it was over-simplistic to suppose that the transitions between geological periods had occurred rapidly. However, given the paucity of evidence at the time, it was just as much an assumption to envisage a long time-scale for the history of the Earth as to suppose the opposite, and, even if the Earth's history had been a long and largely uneventful one, there could be no valid reason to exclude the possibility that, on rare occasions, major catastrophic events had taken place. Cuvier had not speculated about the cause of the catastrophes he believed to have taken place, or about the origin of the species which replaced the ones made extinct, except to say that they could not have evolved from previous species, as supposed by his contemporary, Jean-Baptiste de Lamarck. The British catastrophists accepted that the catastrophes were caused by natural processes, but they too denied the possibility of evolution, so maintained that God must have created new species after each extinction episode, rather than in a single event as stated in *Genesis*. Lyell's view also incorporated a creation scenario. Whilst rejecting the concept of catastrophic extinctions, he believed that, at the end of a geological period, species died out in gradual fashion and were replaced by new species, not through evolution or divine intervention, but by a process of creation designed by God (*PPE* pp. 23-35, 42-53).

Charles Darwin presented his theory of evolution by natural selection to the general public in 1859, in *The Origin of Species*. Strongly influenced by Lyell's geological uniformitarianism, Darwin envisaged evolution taking place in a gradual, even-paced fashion, in a relatively stable environment. However, in 1831, Patrick Matthew had proposed a theory of evolution, operating within a framework of catastrophic extinctions, with essentially the same mechanism as that presented by Darwin twenty-eight years later (*PPE* pp. 60-71). Did Darwin take his ideas from Matthew? In *PPE*, p. 64, I wrote, "Darwin was out of the country until 1836 so it is likely, as he subsequently maintained, that he remained unaware of Matthew's ideas until they were pointed out to him in 1860".

However, Mike Sutton, a lecturer in criminology, has since carried out research which shows that several naturalists who were associates or correspondents of Darwin, including three known to have been influential in the development of his theory, had referred to Matthew's ideas about evolution in published works, so it would seem unlikely they had not mentioned them to Darwin, particularly since Darwin's celebrated phrase, "the process of natural selection" bears a marked similarity to Matthew's phrase, "the natural process of selection" [39].

Returning to the 19th century British catastrophists, it was noted in *PPE* that they adopted a perfectly rational model to explain periodic episodes of catastrophic extinctions – the one proposed in 1829 by a French mining engineer, Léonce Élie de Beaumont. This model supposed that the Earth had been an incandescent body at the time of its formation and, as it cooled in gradual fashion, it also contracted, causing an intermittent wrinkling of the crust, which resulted in mountain-building, widespread floods and extinctions of species. However, as evidence accumulated during the second half of the 19th century, it became clear that there had been no world-wide episodes of mountain-building, and no

association between mountain-building and mass extinctions of species. Hence the Élie de Beaumont model had to be abandoned, leaving catastrophism without a viable scientific basis. Catastrophist models involving impacts of comets and/or asteroids were proposed, but these received very little attention. Aristotle's view that the corrupt Earth was sealed off from the perfect heavens created a mind-set which persisted into the 19th century, and reports that rocks had been seen falling from the sky were either dismissed as lies or explained away by assuming the rocks had been thrown into the air by volcanic eruptions. Even when it became established that meteorites (as they came to be known) had arrived from space, there was no known instance where the fall of one had caused more than a little localised damage. As for comets, William Whiston and Edmond Halley, during the 17th century, had both attempted to associate Noah's Flood with a cometary catastrophe, but Isaac Newton, in his *Principia Mathematica* of 1687, wrote that the orbits of comets had been determined by a benign God, so Earth should be safe from cometary catastrophes. That was the view which prevailed and, indeed, although sightings of comets gave rise to fear and wonder, the comets passed by without causing any harm. So, there no longer seemed to be any basis for catastrophism. Uniformitarian geology, incorporating Darwin's gradualistic theory of evolution, became firmly established as the dominant paradigm. That was still the situation in the 1950s and 1960s, when catastrophists such as Immanuel Velikovsky and René Gallant raised challenges to uniformitarianism (*PPE* pp. 8-13, 31-32, 55-59, 72-83, 114-124).

Resurrection

As is well known, Velikovsky gained a large popular following in the years after the publication of his book, *Worlds in Collision*, in 1950, but there was an overwhelmingly hostile reaction from academic scientists to his theory that major changes in planetary orbits had occurred during the historical period. Some individuals even made attempts to suppress the book. A few other academic scientists, particularly Albert Einstein and Harry Hess in the 1950s and Valentine Bargmann and Lloyd Motz in the early 1960s, argued that Velikovsky's ideas should be given proper consideration, the reasons given for this being that Velikovsky had been unfairly treated and that he had made some correct predictions. None of them said they were convinced by Velikovsky's arguments for planetary catastrophism, as opposed to catastrophism in general. In contrast to the controversy which followed the publication of Velikovsky's book, Gallant's book, *Bombarded Earth*, published in 1964, was simply ignored. By this time, very few people doubted that rocks from space struck the Earth on a regular basis, but there seemed no reason to think this process could cause significant catastrophes. Gallant drew attention to large craters on the surface of the Earth and also on the Moon, but it was generally supposed that these had been caused by volcanic activity. Velikovsky, in his correspondence with Gallant before the publication of the latter's book, cited this conventional view as evidence that asteroid impacts could never provide a meaningful alternative to uniformitarianism [40].

Fig. 3. The 1 km diameter Barringer Crater in Arizona, once supposed to be of volcanic origin but now generally believed to have been produced by the impact of a nickel-iron asteroid of around 50 m in diameter (Credit: D. Roddy (LPI)/NASA.

That situation was soon to change. As documented in *PPE*, the problem had been that, whereas some *small* meteorites had been found inside *small* oval craters, consistent with assumptions about likely impact trajectories, no *large* meteorites had been found inside *large* oval craters. In fact, all the large craters found at the surface of the Earth were approximately circular and, at most, only a few meteorite fragments had been found associated with them (Fig. 3). Hence it was concluded that the large circular craters were probably of volcanic origin. However, during the course of the 1960s, it became established that small rocks arriving from space were slowed down by the atmosphere, so those which went on to strike the planet did no more than punch holes in the Earth's surface-layer. In contrast, larger space-rocks (asteroids) maintained a faster speed as they passed through the Earth's atmosphere and exploded with great power on impact. Calculations showed that the impact of an asteroid 1 km in diameter would cause an explosion with a power equivalent to one from more than a million megatons of TNT (i.e. 50 million times more powerful than the atomic bomb dropped on Hiroshima in 1945) and would produce a crater around 15 km in diameter; whilst an explosion from the impact of an asteroid 10 km in diameter would be equivalent to one from around 100 million megatons of TNT and would give rise to an immense crater of about 180 km in diameter. Cometary nuclei would probably be lighter than asteroids of similar size, but, particularly in the case of long-period comets, they would probably be travelling faster relative to the Earth, so they could cause impact explosions of similar power. Over the next few decades, several craters with diameters in the range 100-180 km, dating from times when animal-life existed on Earth, were confirmed as impact structures on the basis of the overall geology

of the sites and mineral analysis, and some much larger impact craters were also identified, which dated from the earlier Precambrian Period (*PPE* pp. 136-137, 197-198).

The findings by geologists examining the surface of the Earth were consistent with those by astronomers in their investigations of the sky. It became apparent that there were a large number of Near-Earth Objects (NEOs), mostly asteroids, some of them in orbits which crossed that of the Earth. Preliminary studies suggested that around a thousand NEOs had a diameter of 1 km or more, which would result in world-wide devastation in the event of an impact with the Earth. To enable such an impact to be predicted and possibly averted, the space agency NASA was given a Congressional mandate to detect and characterise all NEOs of this size. The target was to identify 90% of them by 2008 (*PPE* pp. 197-210).

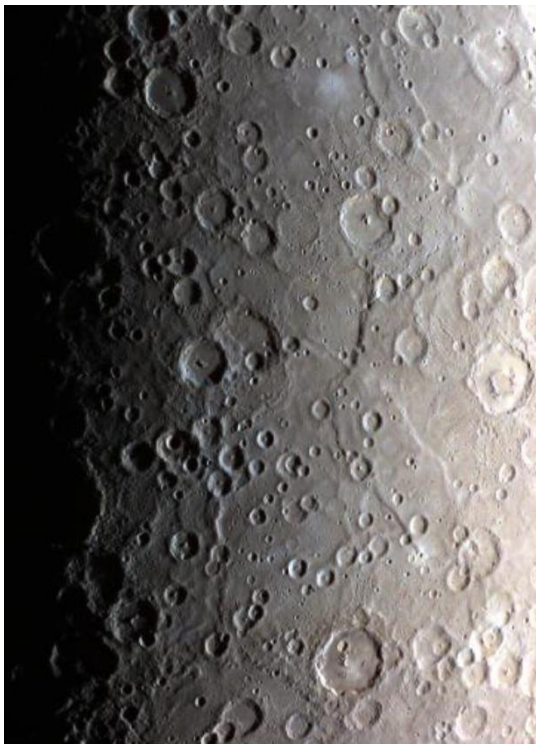

Fig. 4. A typical section of the highly-cratered surface of the planet Mercury (Credit: NASA: PIA18537).

By 2006, it was estimated that about 80% had been detected and, by 2011, that figure had increased to 93%, when it was estimated that only around another 70 had still to be discovered [41]. However, by this time, attention had begun to focus on Potentially-Hazardous Objects (PHOs), defined as ones in Earth-crossing orbits known to bring them within 8 million km of our planet, and with diameters greater than 140 m (capable of causing widespread devastation if striking the Earth). In 2005, Congress gave NASA a mandate to find and catalogue 90% of such objects by 2020. In April 2018, a total of 18,083 Near-Earth Asteroids (NEAs) and 107 Near-Earth Comets (NECs) had been catalogued. Of the NEAs, 888 were estimated to have diameters of 1 km or more (156 of these being potentially-hazardous) and 8,137 to have diameters 140 m or more (1,901 being potentially-hazardous) [42].

Most NEOs are less than 140 m in diameter, yet even so they can pose a significant threat to human life, if they are on a collision-course with the Earth. As was noted in *PPE*, the 1908 Tunguska event, which devastated an area of over 2,000 square kilometres of the Siberian forest, was thought by most astronomers to have involved an atmospheric explosion caused by the arrival of a small asteroid or comet (possibly a fragment of comet Encke), with a diameter of around 50 m. Fortunately, this event occurred in a remote and largely uninhabited region, but Russian scientists pointed out that, had the explosion occurred over St. Petersburg, the entire city would have been wiped out, together with its inhabitants (*PPE* p. 199) [43]. On a smaller scale, in 2012, a streak of light was seen in the dawn sky over the Russian city of Chelyabinsk, followed by a tremendous explosion, which caused buildings to shake and windows to be blown out all over the city. Nobody was killed, but more than a thousand people required medical treatment. Many fragments of a chondrite meteorite were collected together afterwards. It was deduced that the object which exploded was a previously undetected and hence un-named micro-asteroid, with a diameter of about 20 m [44].

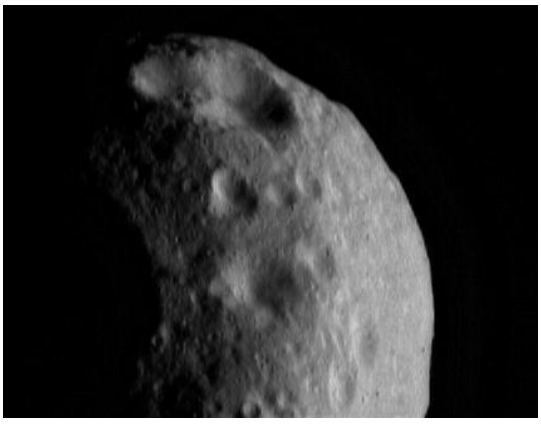

Fig. 5. Part of the Near-Earth Asteroid, Eros (Credit: NASA: PIA02497).

A much larger asteroid, Apophis, with a diameter of around 400 m, was shown in 2004 to be in an orbit which might possibly bring it into collision with the Earth in 2029 or 2036, but further investigations led to an announcement in 2013 that Apophis would pass by safely in both of those years. Indeed, detailed studies have excluded the possibility of any known PHO colliding with the Earth in the next 50 years [45]. However, even so, we cannot be certain of our safety during that period. There are undoubtedly current PHOs still to be discovered and, in any case, as discussed in *PPE*, the Solar System is far more unstable than was once supposed. The widespread finding of impact craters and anomalous features throughout the Solar System (Fig. 4), during and after the 1960s, led to the abandonment of the theory that the planets had been formed in an orderly fashion by condensation from a cloud of gas and dust. Instead, there was a general acceptance of the alternative view

that planets had been produced during a lengthy, violent process involving accretion from dust and pebbles and destructive catastrophic collisions between developing planetoids. Even when this process eventually gave rise to the present planets, in orbits which no longer brought them into contact with each other, smaller cosmic bodies could still cross these orbits, interacting with the planets and with each other. During the 1990s, space probes showed that the main-belt asteroids, Gaspra, Ida and Mathilde, as well as the NEA, Eros (Fig. 5), were irregular-shaped and cratered, consistent with the developing view that NEAs had been ejected from the main-belt as a result of collisions with other asteroids. Cometary nuclei were thought to be little more than "dirty snowballs" but, unexpectedly, probes found that the nuclei of short-period comets, Halley and Borrelly, had dark, insulating crusts, with jets of volatile gases (mainly water vapour) and dust emerging as jets through gaps in the crust. As with the asteroids, they were irregular-shaped and cratered, indicating they had been involved in many collisions before arriving in their present orbits. Since there was no reason to suppose these processes had come to an end, the Earth would continue to face ever-changing threats from NEAs and NECs. Furthermore, long-period comets and perhaps even larger Centaurs could suddenly appear, plunging towards the Inner Solar System, with no way of knowing whether they would be on a collision-course with the Earth, or whether they would fragment dangerously when coming close to the Sun (*PPE* pp. 188-196).

Further developments have re-enforced the picture presented in *PPE*. It is now generally accepted that planets changed their orbits in the remote past. That they might have done so in more recent times cannot be said to be impossible, but arguments that this actually happened rely heavily on interpretations of myths and ancient writings, and alternative interpretations are possible, involving aurorae, supernovae, planetary plasma tails and/or comets [46]. It cannot, however, be doubted that smaller cosmic bodies have moved around the Solar System, interacting with other cosmic bodies, in recent times as well as in the remote past. Probes sent out to asteroids and comets in the new millennium made findings consistent with earlier ones, with main-belt asteroids Ceres, Vesta, Annefrank, Lutetia and Steins, NEAs Toutatis and Itokawa, and short-period comets Wild 2 (Fig. 6), Tempel 1, Hartley 2 and Churyumov-Gerasimenko all showing scars from previous encounters with other cosmic bodies [47]. Clear evidence has also emerged of the Earth being at potential risk from Centaurs in the Outer Solar System and also from objects originating beyond the Solar System, In October 2017, a cigar-shaped object around 400 m in length, nicknamed Oumuamua, was observed travelling rapidly through the Solar System before it returned to interstellar space [48].

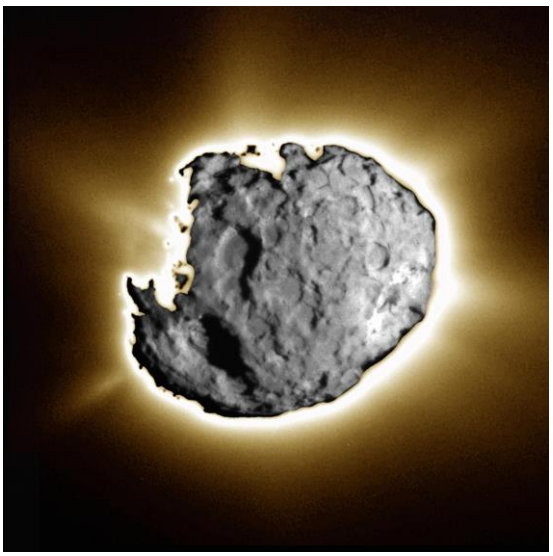

Fig. 6. Comet Wild 2 (Credit: NASA: PIA05578).

As discussed in *PPE*, nearby supernova explosions could be another cause of catastrophes on Earth. In 1954, Otto Schindewolf proposed this as the mechanism for the mass extinctions of species which had occurred at the end of the Permian Period. This same mechanism was invoked by Dale Russell and Wallace Tucker in 1971 to account for the extinction of the dinosaurs at the end of the Cretaceous Period. Others argued that purely terrestrial mechanisms should not be overlooked as possible causes of catastrophes, pointing out that there had been huge outpourings of volcanic lava at the end of both the Permian and Cretaceous Periods, Explosive volcanic eruptions could be much more powerful than once supposed, for the eruption of Krakatoa in the East Indies in 1883 generated significantly more power than the Tunguska event of 1908, and tsunamis produced by the blast killed almost 40,000 people. Furthermore, it has been estimated that the super-eruption 75,000 years ago of Toba, also in the East Indies, was perhaps 100 times more energetic than the Krakatoa blast, for it left a caldera over 50 km in diameter. Earthquakes too can be devastating on a local scale, and more widely if they generate tsunamis. The Lisbon earthquake of 1755, together with the tsunami it generated, devastated the Portuguese capital. Around 30,000 people were killed, with a similar number dying afterwards from disease and starvation (*PPE* pp. 134-135, 210-214).

Amos Nur, the Wayne Loel Professor of Earth Sciences at Stanford University, who had argued in a paper presented at the Second SIS Cambridge Conference in 1997 that earthquakes played a major role in the collapse of great population centres in the Near East at the end of the Bronze Age, went on to write at greater length on this subject in a book published in 2008. In this work, *Apocalypse*, he wrote that his researches had vindicated the catastrophist conclusions of Claude Schaeffer, which had been derided when presented to the public 60 years previously. Another respected scholar, Douglas Erwin, Curator of the Department of Paleobiology at the Smithsonian's National Museum of Natural History, came to the conclusion in his 2006 book, *Extinction*, that extensive volcanic activity had played a significant role in creating the environmental crisis which resulted in the mass extinctions at the end of the Permian Period, and he didn't

exclude the possibility that an extraterrestrial impact might also have been involved. A third, Adrian Melott, Emeritus Professor of Physics and Astronomy at the University of Kansas, drew attention in a 2018 article to isotopic evidence indicating that cosmic rays from a supernova explosion had reached the Earth around 2.6 million years (Myr) ago, providing a plausible mechanism for the switch from forests to grassland in East Africa at around that time, with likely implications for the progress of human evolution [49].

A supernova results from the explosion of a moderately-sized star, and its dangerous effects have only a limited range. However, it is now known that the core-collapse of a more massive, rapidly-spinning, star would result in a hypernova explosion, sending out a brief, narrowly-focused gamma-ray burst (GRB) with immense energy, remaining dangerous over a much longer range than the cosmic rays from supernovae. Similar GRBs could be produced if two neutron stars collide. If the Earth happened to be in the path of a GRB, ozone would be stripped from the atmosphere, leaving the Earth unprotected from dangerous ultraviolet radiation from the Sun. There is also growing recognition of the importance of plasma in the Universe. It is now apparent that the Carrington Event experienced on Earth in September 1859 (named after the astronomer, Richard Carrington) was in fact a huge plasma event, resulting from a major solar flare, when energy and plasma were ejected from the Sun and struck the Earth. Blood-red aurorae were seen in the skies around the world, telegraph machines caused electric shocks (some machines even bursting into flame) and compasses went haywire. It is quite possible that plasma events of this nature, on an even larger scale, could have occurred in the more distant past. Hence, from the above, it is clear that there are quite a number of valid catastrophist mechanisms which could have affected the course of life on Earth [50].

Catastrophes and the History of Life on Earth

The Death of the Dinosaurs

As reported in *PPE*, the extinction of the dinosaurs and many other groups of animals at the Cretaceous-Tertiary (K-T) boundary was the last of the six major mass extinction episodes identified around 1960 from the fossil record, the earlier ones (in chronological order) being near or at the end of the Cambrian, Ordovician, Devonian, Permian and Triassic Periods. However, very few evolutionary biologists or palaeontologists (investigators of fossils) saw any reason to think a special explanation was required for these events. By this time, the Modern Synthesis, blending traditional Darwinism with population genetics, had become the overwhelmingly-dominant evolutionary paradigm, and it was believed that the entire course of life on Earth could be explained through the mechanism of adaptive mutation. The occurrence of random mutations would lead to variant forms within a population, and those variants best adapted to their environment would thrive at the expense of others by the process of natural selection, subsequently passing on the advantageous gene to future generations. So, new species which were better adapted to their environment than old species would out-compete them and slowly drive them to extinction. A change in the environment could play a part but, according to the prevailing uniformitarian paradigm, environmental changes always occurred gradually, so the process of evolutionary change would always be a slow one. From the perspective of the Modern Synthesis, the same evolutionary process operated during mass extinction episodes as at other times, although less slowly, but still over a timescale of thousands of years or more. In 1980, George Gaylord Simpson, one of the founders of the Modern Synthesis, gave a brief description of the 'turnovers' which had occurred in the Late Devonian, Late Permian and Late Cretaceous Periods and continued, "It should…be emphasized that these episodes are of long continuation and that they are not sharply defined in time, even as to their beginnings. It has, for instance, already been stressed that that the essential features of the Cretaceous-Tertiary crisis cannot really be localized just as the boundary between those periods. The episodes are part of a long and essentially continuous process" (*PPE* pp. 133-134, 138-143, 146-148).

In that same year, 1980, American palaeontologist Walter Alvarez and his physicist father, Luis (a Nobel laureate), reported in *Science* the finding of abnormally large amounts of iridium at the K-T boundary in Italy, Denmark and New Zealand. An iridium anomaly of this magnitude could only have resulted from a huge extraterrestrial impact or huge outpourings of lava from the interior of the Earth. Since there was no evidence of volcanic activity at any of the sites, it was proposed that a 10 km diameter asteroid had struck the Earth at the end of the Cretaceous Period and caused the mass extinction of species. Within two years, iridium abundance anomalies had been detected at the K-T boundary at 36 sites scattered around the world. Many geologists, chemists, physicists and astronomers gave sympathetic attention to the Alvarez impact hypothesis, but most evolutionary biologists and palaeontologists, whilst now accepting there were questions which needed answering, continued to maintain their belief in uniformitarian timescales. So, in 1982, a prominent British palaeontologist, Beverly Halstead, wrote, "There is still no satisfactory theory to account for the extinction of the dinosaurs, but at least one can discount the extra-terrestrial catastrophic ones, It seems reasonable to interpret the disappearance of the dinosaurs as a process which occurred gradually over millions of years". Yet evidence consistent with a huge extraterrestrial impact, including shocked quartz grains, sanidine spherules, microtektites and soot, as well as iridium abundance anomalies, continued to be found at the K-T boundary at sites throughout the world. On the other hand, it also became apparent that there had been extensive volcanic activity, including the laying down of the immense Deccan traps in India, during the Late Cretaceous, and it was argued that this alternative catastrophist

mechanism could have given rise to the findings at the various sites, and also caused the mass extinctions, over a much longer timescale than in the impact scenario. Charles Officer, an American geologist, emerged as the most vociferous supporter of the volcanic theory. The arguments raged on, throughout the 1980s (*PPE* pp. 215-234, 243).

The first step towards a resolution of the dispute came in 1990, when investigations began on a huge crater, buried under layers of sedimentary rock, near the village of Chicxulub on the northern coast of the Yucatán Peninsular. The crater was 180 km in diameter, consistent with it having been formed by the impact of a 10 km diameter asteroid or comet, and it was dated to the time of the K-T boundary. Furthermore, shocked quartz grains were found associated with it. Nevertheless, Officer and many others remained unconvinced that it was an impact crater, and continued for a time to pursue the volcanic alternative. However, by 1994, very few people were doubting the age or impact origin of the crater. Even so, many began to argue that this impact event was not the cause, or at least not the sole cause, of the K-T extinctions. Debates often centred on whether or not there was reliable evidence of dinosaur fossils from after the end of the Cretaceous Period. Richard Fortey, senior palaeontologist at the Natural History Museum, London, wrote in 1997, "Even if an impact is accepted, a direct link to extinctions is a separate step. This discussion of the K-T crater is at that critical stage in a historical argument where evidence and counter-evidence are paraded through the pages of journals. Things have changed since the early days, because it now seems that it is the critics who are in the more defensive position" (*PPE* pp. 235-243).

That was still the situation when *PPE* was published in 2003. However, one issue which had been conclusively decided by that time was whether the mammals had simply out-competed the dinosaurs. Clearly they hadn't. The fossil record showed that, during the last days of the dinosaurs, there were relatively few mammal species, all of small size, in existence. After the extinction of the dinosaurs, there was a significant time-lag before signs of a recovery, with a radiation of new mammalian species eventually taking over the ecological niches vacated by the dinosaurs. Not until the Oligocene Epoch of the Tertiary Period, after the Palaeocene and Eocene Epochs had come and gone, did the diversity of large mammals begin to compare to that of the dinosaurs of the Cretaceous Period. It seems that the rise to dominance of the mammals, including ourselves, was not inevitable, but a lucky consequence of the extinction of the dinosaurs. Each of the other mass extinction events had similar consequences (*PPE* pp. 244-251). More recently, developments in genetics have suggested that mass extinctions may do more than create vacant ecological space for the radiation of new species. It seems clear that stress can give rise to hypermutations and also to epigenetic changes, so it must be considered possible that a catastrophic mass extinction episode could give rise to a range of variants beyond what was likely to have occurred during normal times [51]

In 2010, an international panel of 41 scientists, having reviewed all the relevant literature, reported in *Science* their conclusion that the Cretaceous-Tertiary mass extinction (by this time renamed the Cretaceous-Palaeogene mass extinction) had been caused by an extraterrestrial impact in the vicinity of Chicxulub. Five years later, in the comprehensive multi-author work, *Evolution: The Whole Story*, Darren Naish, a British palaeontologist, presented the impact hypothesis for the extinction of the dinosaurs as an accepted fact, writing, "In 2010, a group of experts voted to agree that an asteroid impact caused the Chicxulub crater, and that this was a primary cause of the end-of-Cretaceous mass extinction event." Steve Brusatte, an American palaeontologist who has been personally involved in studies of dinosaurs up to the time of their extinction, wrote in his 2018 book, *The Rise and Fall of the Dinosaurs*, "Whatever the exact sequence of events, I'm confident the asteroid was the primary reason that the non-bird dinosaurs died out. If there is one, single straightforward proposition that I would stake my career on, it would be this: no asteroid, no dinosaur extinction" [52].

Mass Extinctions and Cyclic Processes

During the 1980s, as discussed in *PPE*, it became apparent that the major mass extinction episodes were not simply artifacts of the fossil record, caused by the normal processes of evolution operating a little less slowly than at other times, but real events, in which the extinction of many existing species created vacant ecological space for the subsequent emergence of a range of new species. Nevertheless, the primary causal mechanism remained uncertain. There was no fundamental reason to suppose that the same causal mechanism had operated every time but, nevertheless, in each case (except the first, the Late Cambrian extinction, where very little evidence had survived) there were clear indications that volcanic eruptions and other tectonic mechanisms operating within the Earth may have played a significant role, giving rise to features such as flood basalt deposition (as with the Deccan traps), sea-level and climate changes, and oxygen-depletion (anoxia) in the seas. On the other hand, there was also evidence of large extraterrestrial impacts having occurred close to the impact horizons, although, with the exception of the K-T event, there were no worldwide impact-related destruction layers. Conversely, even if the massive impact at Chicxulub was the primary cause of the K-T extinctions (as was eventually accepted), there were indications of other significant extraterrestrial impacts close to the K-T boundary, as well as widespread volcanic eruptions and other tectonic activity, which might have contributed to the severity of the event (*PPE* pp. 255-273). Could the same processes, interacting in complex fashion, have been involved on each occasion?

Back in 1977, Alfred Fischer and Michael Arthur of Princeton University proposed that there was a 32-Myr cycle in tectonic processes which gave rise to extinctions. Five years later, David Raup and John Sepkoski, of the University of Chicago, restricting their analysis to well-documented data, found a 30-Myr periodicity in mass extinctions which, when they refined their methodology further, became a 26-Myr periodicity. The last three extinction peaks in their analysis were the massive one at the K-T boundary followed by a lesser one at the end of the Eocene Epoch and then an even smaller one during the Miocene Epoch. In 1984, a cluster of papers were published in *Nature*, suggesting impact-related mechanisms which might give rise to a 26-Myr periodicity in extinctions. All made the common assumption that a mechanism which propelled comets from their home in the Oort cloud towards the Inner Solar System was required. Two proposals suggested the Sun had a binary partner (subsequently called Nemesis) which disturbed the Oort cloud comets twice in each of its 52-Myr elongated orbits around the Sun. Another mechanism involved an additional outer planet, Planet X, similarly in an elongated 52-Myr orbit around the Sun. The third mechanism, proposed by Michael Rampino and Richard Stothers of NASA, following a suggestion by Victor Clube and Bill Napier, envisaged disruption of Oort cloud comets by molecular clouds or gravitational perturbations every time the Solar System passed through the galactic plain in its up-and-down oscillations. Investigations failed to find any sign of either a solar partner or Planet X, but the Solar System was known to have both a horizontal and vertical oscillation with respect to the galaxy and, according to Clube and Napier, it passed through the galactic plane at intervals of approximately 30 Myr. Nevertheless, the oscillation model, like the other two, was subjected to challenge (*PPE* pp. 274-278).

Meanwhile, Walter Alvarez and Richard Muller, after selecting for analysis the best-dated impact craters with diameters in excess of 10 km from a data-base compiled by Richard Grieve of the Geological Society of Canada, concluded that there was evidence of a cycle of crater formation with a periodicity of 28 Myr, whilst Fischer and Arthur continued to develop their arguments for a periodicity in tectonic processes. In 1993, Rampino and Ken Caldeira identified a 27-Myr periodicity linking extinction events, regressions of the sea, flood basalt eruptions, mountain-building events, changes in sea-floor spreading and anoxic events in the oceans, but there was also evidence of associated impacts, so they suggested a unifying cause, which was more likely to be cosmic than terrestrial. Three years later, Rampino produced further evidence for a periodicity of extinctions linked to impact events, and gave the name ‘Shiva hypothesis’ (Shiva being the Hindu god of destruction and transformation) to the notion that cyclical mass extinctions of life on Earth result from extraterrestrial impacts. All of these claims of cyclical processes were controversial but, regardless of whether there was a strict periodicity, it was becoming generally accepted that the Earth suffers major environmental crises at an average rate of around one every 30 Myr, whatever the primary cause (*PPE* pp. 278-286).

In 2013, physicist Adrian Melott and palaeontologist Richard Bambach re-assessed the situation in the light of improved age determinations and a revised geological timescale and found that a periodicity of extinctions linked to impact events remained a viable theory. Two years later, making use of the improved data, Rampino and Caldeira found that extinction peaks and cratering peaks both seemed to occur with the same 26 Myr periodicity, and that there was a good correlation between extinction events, major impacts and flood basalt eruptions, with a 26-27 Myr period of repetition [53].

Rampino, an earth and environmental scientist at New York University, who has been a consultant for NASA, discussed his ideas, and their historical and current context, in his 2017 book, *Cataclysms*. He wrote, “I was originally one of the doubters of the impact hypothesis. I was still influenced by the ghost of Lyell. But I changed my mind as the evidence for the end-Cretaceous impact at Chicxulub became overwhelming. Given what we now know about the probability of impacts of comets and asteroids, it seems inescapable that large-body impact events have affected the history of life on our planet. Discovering evidence of impacts is not easy, but we have signs of the potential involvement of impacts in several extinctions, and the record is expected to get better. However, the correlation of some extinction events with cataclysmic flood basalt volcanism and related times of ocean anoxia suggests that internal Earth pressures also can create global environmental disasters capable of devastating life. Our planet is truly beset by catastrophic changes from within and from above” [54].

Rampino noted (on p. 55 of *Cataclysms*) a marked reluctance of geologists to accept any significant involvement of impacts in extinction events, other than that at the K-T boundary (which could no longer be denied), commenting that some still proclaimed that the “best explanation for the mass extinctions…involves random, purely terrestrial processes working in concert”. Nevertheless, he acknowledged (on p. 59) that “the jury is still out on the question of cycles in the extinction data”. Later (on pp. 150-157), Rampino expressed the view that theories of terrestrial processes such as plate tectonics were currently incomplete. They could be used to extrapolate backwards and forwards in time from the present, but the histories of the processes could not be derived from first principles. Why, for example, did hotspot volcanism occur where and when it did? From recent findings, it seemed to him “that geology may be on the threshold of a new theory that seeks to explain Earth’s geologic activity in time and space in the context of its astronomical surroundings”. He (and others) had suggested that major impacts could give rise to hotspot volcanism, but could provide no satisfactory detailed mechanism, and, in any case, there were other terrestrial processes which needed to be

explained. As a possible way forward, he noted that Harvard astrophysicists, Lisa Randall and Matthew Reece, had argued in 2014 that the greatest perturbation of Oort cloud comets could be from "dark matter" concentrated at the galactic equator. Rampino pointed out that, according to the calculations of astrophysicists, the passage of the Earth through a clump of dark matter would generate an enormous amount of energy, providing "a plausible hypothesis with regard to the origin of pulses of geologic activity". This, or some other mechanism which "links geologic events on Earth with the structure and dynamics of the Milky Way galaxy", could provide the dimension currently lacking from terrestrial processes, explaining the sub-title of Rampino's book, "A New Geology for the Twenty-First Century" [55].

The Late Pleistocene Extinctions

As reported in *PPE*, there was evidence that the Pleistocene Ice Age was interrupted by a warm spell which began around 14,000 years ago and lasted for about a thousand years. Glacial conditions then returned at the start of the Younger Dryas, the final stage of the Pleistocene, before a more sustained increase in temperatures started around 11,500 years ago, marking the Pleistocene-Holocene transition. Throughout this period, extinctions occurred at different times around the world, but were particularly marked in North America, where three-quarters of the genera of large land-animals (megafauna), including all the mammoths (Fig. 7), mastodons, horses, tapirs andcamels, became extinct between 12,000 and 10,000 years ago. There was much disagreement about whether these extinctions had been caused primarily by climate change or butchering by the Clovis people, who had established settlements in North America by this time (*PPE* pp. 302-312).

Fig. 7. A sculpture of a mammoth alongside the author outside the Galerie de Paléontologie et d'Anatomie comparée, Paris, 1997 (photo: Jan Palmer).

The supposed time-range of the Late Pleistocene extinctions in North America given above had been determined by uncalibrated radiocarbon dating, but it subsequently became generally-accepted that this technique gave dates for Late Pleistocene samples which were around 2,000 years too low. In 2006, in *The Cycle of Cosmic Catastrophes*, Richard Firestone, a nuclear physicist, together with Allen West and Simon Warwick-Smith, set out to explain the puzzle of the anomalous radiocarbon dates and also two other puzzles: the fact that, in North America, all the extinct megafauna and all the Clovis remains were found underneath a widespread "black mat" (a carbon-rich stratigraphic layer); and that small holes were found in many of the bones from under this layer. They proposed that destructive radiation from a nearby supernova explosion entered the Earth's atmosphere around 41,000 years ago, causing some extinctions and increasing the carbon-14 content of the atmosphere. Around 34,000 years ago, the shock-wave from the supernova arrived, causing more extinctions and enhancement of atmospheric carbon-14, as well as bombarding the Earth with ions and small particles, which produced holes resembling buckshot wounds in animal bones. Then, around 13,000 years ago, one or more comets whose orbits had been disturbed by the supernova explosion struck the Earth, causing further extinctions and supplementation of atmospheric carbon-14, as well as destroying the Clovis culture, covering much of North America with the black mat, and lowering temperatures. The authors claimed evidence of enhanced iridium, glasslike-carbon, nanodiamonds and soot, as found at known impact sites (and the K-T boundary), in the black mat (which they named the "Clovis layer"). Meanwhile, in Western Europe, Han Kloosterman, a Dutch industrial geologist, had been investigating a similar black layer, known as the "Usselo Horizon", dating from the same time (the interface between the warm Allerød and the glacial Younger Dryas) and, in an article in a Dutch journal in 2000, he attributed this to a cometary impact [56].

Kloosterman began to collaborate with analytical chemist Wendy Wolbach of DePaul University, Chicago, who had previously investigated the K-T boundary layer, and these then joined forces with the Firestone group, with prominent geologists such as James Kennett of the University of California and Ted Bunch of Northern Arizona University also becoming part of the team. Their ideas received a favourable reception from some but were strongly criticised by others, including physicist Tyrone Daulton of Washington University, St Louis, palaeobotanist Andrew Scott of London University and geologist Nicholas Pinter of Southern Illinois University. Generally, there was some validity in the criticisms but sadly, reminiscent of the past, there were instances when reasons given for rejecting a catastrophist theory defied belief. For example, in 2012, Annelies van Hoesel and other geologists from Utrecht concluded that there was no evidence of an impact at a site in the Netherlands, even though cubic nanodiamonds, recognised as impact markers, were present. They said the nanodiamonds must have been formed by wildfires, even though there is no known mechanism by which this could happen. In *C&C Review* 2115:1, I gave an account of the key issues in the debates, up to the publication of a major 26-author article by the impact group in the *Journal of Geology* in September 2014, which

reported the finding of nanodiamonds in the Younger Dryas onset boundary at 24 sites in USA, Mexico, Canada, Greenland, England, Belgium, Germany, Spain and Syria, consistent with a cosmic impact around 13,000 years ago [57].

Since then, the debates have continued as before. So, for example, the impact hypothesis was challenged in 2017 in two articles by Scott, Pinter and others. No theory can be above challenge, and it was generally acknowledged that a cometary impact causing devastation over such a large area should have produced a huge crater, yet this had not been found. However, there would be no problem if, rather than a single large comet, a cluster of smaller comets, perhaps produced by the fragmentation of a larger comet, as in the Clube-Napier theory, had been responsible for the devastation. In 2017, Jonathan Hagstrum of the US Geological Survey, together with Firestone and other members of the impact group, reported the results of investigations of Late Pleistocene Alaskan and Yukon frozen "muck" deposits, containing highly disrupted and damaged animal and plant remains. They found large quantities of impact-related spherules and platinum abundances, but dating studies showed that the animals had lived at different times. It was concluded that the mucks and their associated remains were blast deposits resulting from several episodes of airbursts and impacts within the northern hemisphere during the Late Pleistocene, possibly resulting from encounters with cometary debris generated by fragmentation of a large comet. The megafaunal extinctions were the culmination, around 13,000 years ago, of a series of similar but smaller events. Another major paper from the impact group came soon afterwards, published in the *Journal of Geology*, in two parts, early in 2018. The 27 authors, headed by Wolbach, included Firestone, West, Kennet, Bunch and, for the first time in this company, Bill Napier. They reported that ice-core sequences from Greenland, Antarctica and Russia, and lake, marine and terrestrial sequences from North, South and Central America, Europe and Western Asia, all showed a major peak in biomass burning at the Younger Dryas onset boundary [58].

Natural Catastrophes in the Holocene Epoch: Atlantis, Noah's Flood and Sodom

PPE also reported disagreements about the cause of the Pleistocene-Holocene transition, around 11,500 years ago. According to the Clube-Napier theory, the clearing of a cometary dust-cloud from the atmosphere, which had helped to maintain glacial conditions, was a significant factor. Others, including Fred Hoyle, suggested the involvement of an extraterrestrial impact in an ocean, and, since Plato had written that the civilisation based on a large Atlantic island named Atlantis had been destroyed in a catastrophic flood 9,000 years previously, i.e. around the time of the Pleistocene-Holocene transition, Otto Muck and Emilio Spedicato argued that such an impact had also been responsible for the destruction of Atlantis (Muck placing Atlantis in the mid-Atlantic and Spedicato in the Caribbean). However, no convincing evidence of an impact at this time could be found. Some suggested a change in the axial-tilt of the Earth may have caused the transition. A conventional view was that the end of the Ice Age resulted simply from changes to currents in the Atlantic Ocean (*PPE* pp. 125-130, 312-320).

As the glaciers retreated, for whatever reason, catastrophic floods ravaged parts of North America on several occasions. On a more global scale, the release of water which had previously been stored as ice eventually led to a sea-level rise of more than 100 m. It was once assumed that this was a gradual, even-paced process, but investigations showed that, at least on occasions, it took place in rapid fashion. Around 11,000 years ago, average temperatures rose by almost 10ºC in a short period of time, probably less than a decade. Low-lying regions throughout the world were flooded as sea-levels rose and, even if the seas were rising in a gradual fashion, the local effects could be catastrophic. So, for example, it seemed that the Black Sea was sealed off from the Mediterranean by a natural dam in the Bosporus region which eventually burst around 5600 BC, allowing water to rush into the Black Sea, causing catastrophic flooding of its coastal regions. Evidence for this was presented in 1999 by Columbia University geologists, William Ryan and Walter Pitman, who went on to argue that recollections of this cataclysmic event might have been passed on by people who managed to escape and made their way to Mesopotamia, giving rise to the Sumerian flood-myth of Uta-Napishtim in the Epic of Gilgamesh and, in turn, to the *Genesis* story of Noah and his family (*PPE* pp. 6, 312-315).

Plato's story of the catastrophic flooding of Atlantis received particular public attention, particularly following the publication of some best-selling books making sensational claims. Whereas the Scottish anthropologist, Lewis Spence, in his 1926 book, *History of Atlantis*, suggested that the stone-age Cro-Magnon people, who came to dominate Europe, might have been refugees from Atlantis, these authors went far beyond anything which could be inferred from the writings of Plato in claiming that Atlantis was a remarkably advanced civilisation, and, furthermore, they made much of the ideas of the occultists and the predictions of the American psychic, Edgar Cayce. So, for example, Charles Berlitz, in his 1984 book, *Atlantis*, and, twelve years later, Robert Bauval and Graham Hancock, in *Keepers of Genesis*, drew attention to some of Cayce's prophecies about Atlantis, but these subsequently turned out to be false and, more importantly, the authors failed to present any meaningful evidence of a super-civilisation in the Stone Age. Some other authors, in more scholarly fashion, questioned whether all the details given by Plato were meant to be taken literally, and tried to find a scenario in which Plato might have been referring to a much more recent civilisation. So, in 1969, Angelos Galanopoulos argued that Plato's catastrophe might have been the Bronze Age eruption of Thera, producing a

caldera 10 km in diameter and generating a tsunami which battered the coastal cities of the Minoan civilisation of Crete. Similarly, in 1992, Eberhard Zangger argued that Plato was basing key elements of his Atlantis on Troy, which fell at the end of the Bronze Age, whilst Peter James, in 1995 in *The Sunken Kingdom*, proposed that Tantalis in Asia Minor, which also thrived in the Late Bronze Age, provided Plato with his main ideas (*PPE* pp. 130-132, 212-213, 316-335).

More generally, the main catastrophic Bronze Age destructions were, as documented in numerous SIS articles by Moe Mandelkehr, those at the end of the Early Bronze Age. Of particular note, Marie-Agnès Courty, a geologist at the French Centre for Scientific Research, reported at the Second SIS Cambridge Conference, in 1997 (Fig. 8), evidence of a massive explosion over northern Syria at this time which resulted in the abandonment of Tell Leilan and brought about a climate-change that may have initiated the collapse of the Akkadian Empire. In 1980, Walter Rast and Thomas Schaub had argued that five Early Bronze Age sites near the south-eastern corner of the Dead Sea might have been the "five cities of the plain" mentioned in *Genesis*, so their destruction at the end of the Early Bronze Age was consistent with the Biblical account of the destruction of Sodom and Gomorrah (*PPE* pp. 119, 336-346).

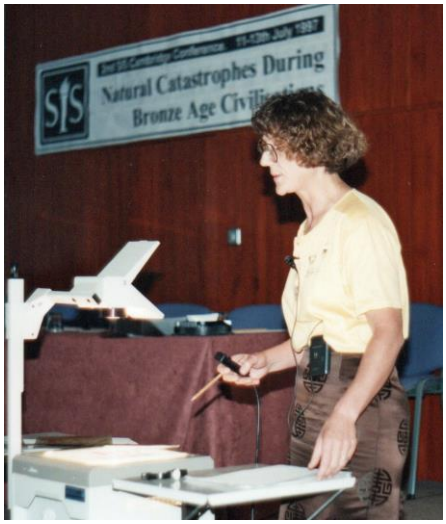

Fig. 8. Marie-Agnès Courty speaking at the Second SIS Cambridge Conference, 1997 (photo: T Palmer)

Almost a decade after the publication of *PPE*, Robert Schoch argued in his 2012 book, *Forgotten Civilization*, that a major plasma event finally brought the glaciations of the Pleistocene to an end. Then, in 2015, Rupert Holms unveiled a new catastrophist theory in the first volume of his *Star-Core Trilogy*. According to this theory, a large companion-star to the Sun underwent a supernova explosion 4.6 billion years ago, leaving behind a star-core which is only twice the size of the Earth but extremely dense and magnetic. This currently passes close to the Earth every 4,000 years, causing global catastrophes of flood and fire. An encounter 11,600 years ago caused the Younger-Dryas onset event (over 1,000 years later than generally supposed) closely followed by the Pleistocene-Holocene transition. Holms went on to argue that the next encounter, around 5600 BC, resulted in an enormous deluge from the heavens, causing an enormous flood on all the continents of the Earth. This gave rise to numerous flood myths, including the story of Uta-Napishtim and, subsequently, of Noah. Meanwhile, the Black Sea Flood Hypothesis of Ryan and Pitman generated fierce debates, because Russian scholars pointed out it ignored the fact that there had been catastrophic flooding around waterways between the Black Sea and the Caspian Sea during the early Holocene, so flood water could have reached the Black Sea from the northeast as well as from the southwest, and at different times. Nevertheless, regardless of specific details about mechanisms and timing, there seemed no shortage of possible sources for the myth of Uta-Napishtim [59].

Proposals and debates about the possible location of Plato's Atlantis, if indeed there was one, have also continued. So, for example, Stavros Papamarinopoulos, a geophysicist at the University of Patras, has pointed out that *nesos*, the word used by Plato to describe Atlantis, and usually translated as "island", means any piece of land largely or completely surrounded by sea, so could apply to the Iberian Peninsula. Hence, the silver-rich state of Tartessos near the mouth of the Guadalquivir River in southwestern Spain, prominent several centuries before the time of Plato, is, in geographical terms, a plausible candidate for Atlantis, as had been suggested by Adolf Schulten in 1927. The catastrophic destruction by flooding might have applied to its capital city, somewhere near the Atlantic coast of Spain, rather than to the entire country. In 2015, Mark Adams published the results of an investigation of current theories about Atlantis, without coming to any firm conclusions [60].

Mary-Agnès Courty continued to investigate evidence relating to the blast which devastated the region around Tell Leilan at the end of the Early Bronze Age and found that such evidence covered a far greater area than expected, showing up at sites in both the southern and northern hemispheres. In 2006, she proposed that a 1 km diameter asteroid plunging into the Indian Ocean had been the cause of the blast. A few centuries after the destruction and abandonment of Tell Leilan, several Middle Bronze Age cities in the Southern Jordan Valley north of the Dead Sea, including Tall el-Hammam, were similarly destroyed and abandoned. Steven Collins of Trinity Southwest University, Albuquerque, who has led the archaeological investigations at Tall el-Hammam since 2005, came to the conclusion that this was the site of the biblical Sodom. More importantly, from a catastrophist perspective, Collins concluded that the destructions may have been caused by a cosmic airburst [61].

Conclusion

The last section of *PPE* began:

> Regardless of the details of what happened at any particular time, it is clear that a major change of thinking has taken place. In contrast to the situation only twenty years ago, mainstream scholars are now prepared to take seriously the possibility that catastrophic events, including ones of extraterrestrial origin, may have shaped the course of life on Earth. Such possibilities have been widely discussed for events which took place millions of years in the past, particularly the mass extinction episodes in the stratigraphic record, but they could also be of relevance to events in more recent times, affecting human history or pre-history. The very mention of Atlantis, Noah's Flood or Sodom and Gomorrah still tends to suggest to some scholars an inevitable association with unscientific nonsense or religious dogma. However, that does not necessarily follow, despite the fact that some writers on these topics continue to pursue their own agenda, whether through self-delusion or the desire to make money out of a gullible public. A significant number of serious scholars now accept that these and other ancient legends could be based on some genuine memory of a catastrophic event, and it would be just as unscientific to deny that possibility as to claim that the legends must be correct in every particular. With the developments of the past few years, there is no longer any intellectual justification for dismissing catastrophist arguments out-of-hand, so these, whether right or wrong, should now be considered on exactly the same basis as gradualist ones.

There have been significant developments in matters of detail during the 15 years since that paragraph was written, but its message still seems appropriate today.

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