A Flashback on the Dawn of the Meteorite Impact/Extinction Theory

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A flashback on the dawn of the meteorite impact/extinction theory

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Presented are my personal recollections on some of the major contributions by the Alvarez groups to the birth and development of the meteorite impact/extinction theory.

Prelude

A long history preceded the publication of two papers (Alvarez et al. 1980; Smit and Hertogen 1980) on a hypothesis that was to change the way we think about mass extinctions. The idea of a major impact ending the reign of the dinosaurs had been launched earlier, albeit without a scrap of evidence. Many other hypotheses had been put forward and had fared no better by lack of supporting data. De Laubenfels (1956) introduced "one more hypothesis", a meteorite impact, and suggested that the heat flash had killed off the dinosaurs. The problem with this and other hypotheses (i.e., diseases, egg predation, pituitary gland anomalies, oversize, overspecialisation, magnetic reversal, sea level changes, etc.) is that they account for only small group of (generally) terrestrial vertebrates, but that they do not explain the simultaneous extinction of marine life.

De Laubenfels's impact idea was inspired by the proximity in 1937 and 1941 of the 1km-sized asteroid Hermes, at only 1,6 times the Earth-Moon distance. He even estimated the frequency of large, 10 km-sized planetesimal collisions correctly: about 2–3 such impacts during the Phanerozoic, a number subsequently confirmed by better observations and statistics (Dachille 1977; Grieve et al. 1995).

Nobel laureate Harold Urey suggested in 1973 that geologists should be on the lookout for (micro)tektites at geological boundaries, especially at the Cretaceous–Paleogene (K/Pg) boundary, but failed to find them (Urey 1973). Christensen et al. (1973) analysed in detail the Stevns Klint K/Pg boundary clay by Atomic Absorption Spectroscopy (AAS) and found anomalously high concentrations of Cr and Ni. However, further than a comparison with anaerobic black shale enrichments they did not go, although the enrichments were much greater than those in black shales.

In the 1960s we learned from Professor H.A. Brouwer (personal communication 1969) that the craters on the moon might be volcanic. In our petrology classes we were taught that the Sudbury igneous body was a volcanic lopolith (Lowman 1992) and O'Keefe (1976) believed that tektites could be produced by lunar volcanoes. The Apollo lunar missions changed all that and generated detailed research of impacts and meteorites. Urey (1957), Shoemaker (1963) and others convincingly demonstrated that both the Moon and the Earth were saturated with impact craters, but that those on the Earth were largely eroded away. Impacts slowly came to be seen as "a matter of fact" in the geological record.

In the early 1960s, in particular in the Chicago Fermi laboratories, the analytical technique of Neutron Activation (INAA) (developed by George de Hevesy) was used for the detection of many trace elements, in particular iridium. Barker and Anders (1968) and Crocket and Kuo (1979) used this technique to estimate the accretion rate of cosmic matter. They could apply this estimate because it had previously been discovered that iridium in cosmic matter (meteorites) was orders of magnitude more abundant than in terrestrial crustal materials (~500 versus 0.02 ng/g). Iridium is a special element in INAA. It has a relatively large "neutron capture cross section", which means that ^{191}Ir absorbs easily a neutron to become the radioactive isotope ^{192}Ir. This ^{192}Ir decays with a half life of 74 days emitting two easily identifiable gamma rays of 316 and 468 kev energy. Therefore, among the Platinum Group Elements (PGE), it is by far the easiest to identify.

Italy

Around 1976 Luis and Walter Alvarez became intrigued by a 1cm-thin clay layer that separates the Cretaceous from the "Tertiary", because Isabella Premoli Silva had told Walter that all pelagic oceanic unicellular life with a calcareous skeleton became extinct, coincident with the dinosaurs, right at that clay layer. Premoli Silva had earlier discovered the diminutive *Globigerina eugubina* fauna (Luterbacher and Premoli Silva 1964) that documented the early recovery phase after the K/Pg boundary mass extinctions; the specific epithet *eugubina* being the Latin name of Gubbio. Building on a multidisciplinary study which established the magnetostratigraphy of the Upper Cretaceous through Paleogene in the Bottaccione gorge near Gubbio (Alvarez and Lowrie 1977), the Alvarez group tried to estimate the duration of deposition of the K/Pg boundary clay, assuming a constant rain of cosmic material onto the surface of the Earth. They inferred that the amount of cosmic material could be estimated by measuring the amount of iridium in the K/Pg clay, as established by Barker and Anders (1968). However, instead of finding some enhanced levels of Ir predicted by a constant cosmic influx, they documented a large Ir anomaly. Their findings were initially presented at the American Geophysical Union (AGU) fall meeting of 1978, where they assumed an extraterrestrial source but rejected the supernova hypothesis. The rest is history.

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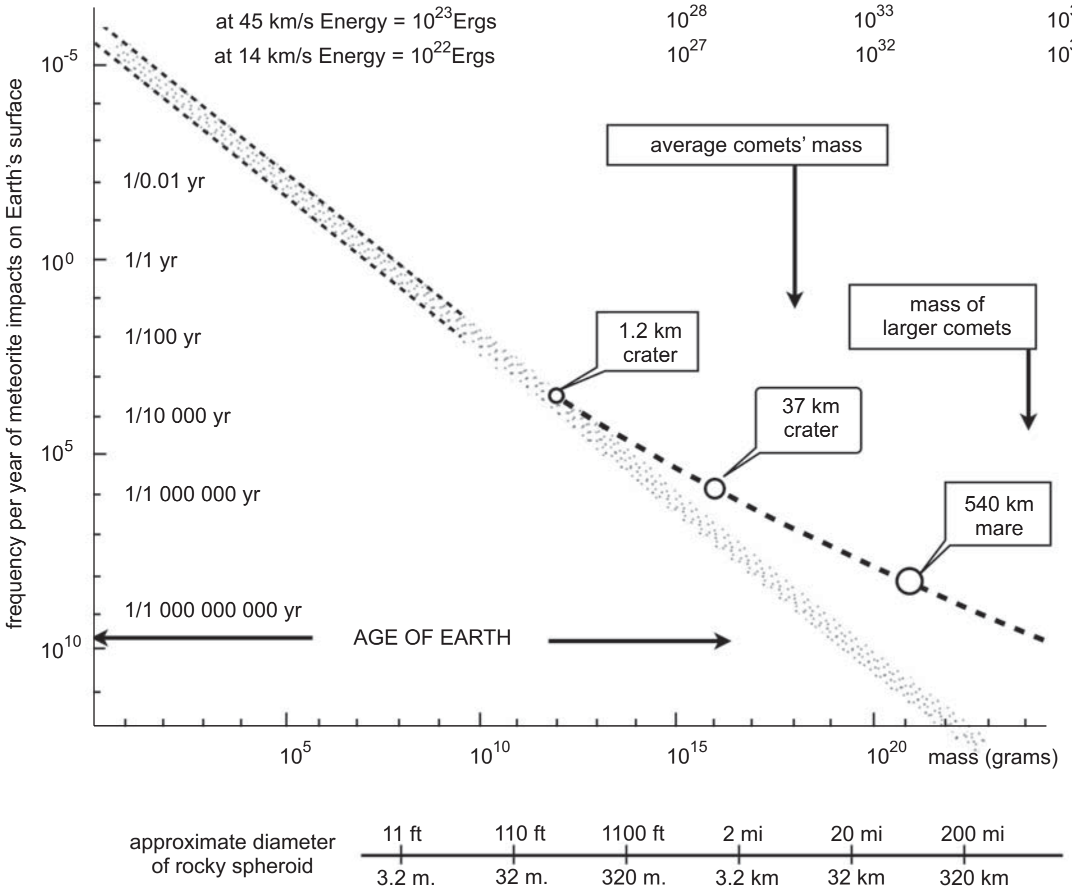

Fig. 1. Plot of the relationship between size, mass, energy and frequency of smaller and major impacts in the history of planet Earth. These frequencies are, after 35 years, still valid! (redrawn from Dachille 1977: fig. 2).

Spain

From 1975, I had worked in the Barranco del Gredero, near Caravaca (southeast Spain) on the same problem: why do planktonic foraminifera become extinct at the K/Pg boundary? As member of the planktonic foraminifera service group at the Geological Institute of the University of Amsterdam (UvA), I analysed in 1973 a sequence of samples, taken by Jacobus Hermes from the topmost Maastrichtian, to identify all planktonic foraminifera in these highly diverse, latest Cretaceous assemblages. The next sample, a dark clay, yielded only sparse, small specimens. I became intrigued by the K/Pg boundary problem, because the boundary was invariably sharp as a knife in the roughly thirty sections in the Subbetic area that I had previously studied. This was not supposed to be so, because the pelagic sediments above and below the K/Pg boundary were not disturbed at all. The results of analyses of the Barranco del Gredero (Smit 1977) failed to demonstrate any trend in the foraminiferal populations up to the K/ Pg boundary, such as a change in size of tests, a change in relative and absolute abundances of foraminifera, or a change in the planktonic/benthic (P/B) ratio. Following up on the absence of any foraminiferal changes, I undertook in 1977 an INAA analysis of a set of 100 samples, ranging from 15 m below to 50 m above the K/Pg boundary in the Barranco de Gredero. The K/Pg boundary interval was analysed in mm- to cm-detail. The computer-generated output showed highly anomalous concentrations of Ni, Cr, Co, As and Sb, at the base of the black clay, but initially not iridium. These results were almost identical to those presented by Christensen et al. (1973) from Stevns Klint.

Further developments

Similar to the absence of foraminiferal change approaching the K/Pg boundary from below, none of the ~30 analysed elements displayed any change in content towards that boundary (Smit and ten Kate 1982). Seemingly, there was no further clue as to the cause of the mass extinctions hidden in the late Maastrichtian record. On the other hand, the absence itself of appreciable elemental and biotic changes preceding the mass extinction level was an important pointer. This meant probably that all earth-bound killing mechanisms could be excluded! Those mechanisms, inclusive of volcanism, climate changes, plate tectonic configuration alterations such as opening and closing of major seaways, Arctic flooding etc., are supposed to leave traces in the record immediately preceding the mass extinctions, and there was none. The exclusion of earth-bound mechanisms leaves only extraterrestrial causes, like a supernova explosion or a meteorite impact.

Around the same time I read the paper by Dachille (1977), in which that author plotted the frequency of large meteorite impacts (Fig. 1). It suddenly dawned upon me that a large meteorite impact was a distinct possibility. In May 1979, the report in the *New Scientist* of the 1978 AGU fall meeting attracted my attention. The Alvarez group had found iridium in the exactly the same K/Pg boundary clay layer at Gubbio, by the same analytical method (INAA) that I had applied to the Caravaca clay!

I visited the Gubbio section in 1978. However, I was convinced that the completeness and time resolution of the Gredero section was much better than the one at Gubbio, so iridium should have been found there as well. Jan Hertogen had just returned from a post-doc at Chicago with Ed Anders. At Gent University (Belgium) he performed INAA for detection of PGE, and he immediately agreed to analyze some samples from Caravaca. He quickly found the missing iridium concentrations, that were highly anomalous at the base of the K/Pg boundary clay. I was not convinced yet that the supernova hypothesis should be dismissed: both supernova and meteorite impact are extraterrestrial, and could have delivered an enhanced Ir flux, and could be the cause of the unannounced extinctions due to enhanced irradiation levels both on land and in the sea. The supernova hypothesis was launched earlier by Dale Russell (Russell and Tucker 1971), and it was estimated that a supernova at <50 light years distance, probably within damage range, would happen every 100 myr or so, on average (Russell and Tucker 1971). Besides, it is difficult to imagine that even a large impact of a 10 km-sized meteorite could have had global consequences.

In that respect I have to mention another crucial contribution by the Alvarez group: one that tied a meteorite impact to the mass extinctions. In order to eliminate the phytoplankton, the basis of the food chain, of which planktonic foraminifera depended, it was necessary that the "lights were shut for one year". This scenario had already been discussed two years earlier during the K-tec workshop in Ottawa, November 1976 (Beland et al. 1976). However, a meteorite impact was not even mentioned in passing, while the supernova explosion or a solar superflare, and even volcanism, were discussed at length.

Alvarez's dust cloud scenario, blocking the sunlight for a year, caused by the meteorite impact, held just the right ingredients to extinguish phyto- and zooplankton species on a global scale. We now have a better knowledge of what kind of dust and aerosol particles were hurled into the atmosphere by the Chicxulub impact. But basically, the dust cloud scenario still stands as the best explanation!

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