THE TROUBLE WITH NEMESIS

BY

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ABSTRACT. -- Using a conservative sample of five major impact events with age uncertainties ≤ ± 2 Myr, a pattern of accretion events post-synchronous with climatic cooling and withdrawal of the seas from the continental shelves emerges. It is suggested that the probability of producing tectites and other impact signatures increases as the probability of impact on land or shallow water (≤ 50m) increases, as when sea level falls and larger portions of the Earth's surface are exposed. The assertion that an unseen solar companion triggers mass extinctions by periodically showering the Earth with comets appears incorrect. The often cited "cycles" (assuming they are not an artifact of a small sample) may in fact arise from climatic trends that, among other things, trigger extinctions (rather than the impacts being the primary cause of the extinctions).

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In their 22 November response to Weissman's[1] criticism of the "Nemesis" theory, Muller et al[2] cite the subsidence of heavy meteoritic bombardment of the moon some 3.9 x 10^9 yr ago as supporting their proposal that a companion star once moved with the sun in an orbit so tightly bound that the inner solar system (and presumably the moon) was showered continually by gravitationally dislodged comets. The subsidence is implied to result from Nemesis' scatter to a wider orbit. As Stoff and I[3] have emphasised, the subsidence seen 3.9 x 10^9 yr ago is consistent with an exponentially decreasing frequency of accretion events that would be expected after the initial collapse of the presolar nebula. We need not introduce companion stars to explain the observed exponential curve. (Conversely, possible support for the Nemesis theory comes from spikes in the declining curve, which mark periods of unusually intense bombardment. Stoff and I[3] suggested that the spikes result from new material entering the solar system and/or from the shatter of asteroids.)

An additional problem with the Nemesis scenario is that Sepkoski and Raup's[4,5] census of extinction events, which indicates a 26.2 ± 1 Myr cycle of biological crises, is based on compilations of literature in many fields of paleontology spanning several decades. The literature is a shambles, requiring specialists to interpret what has been shuffled from one group of organisms to another at various times in the past. Hence, a re-analysis of extinction data is now in progress. "At a recent scientific meeting," writes Tappan[6], "Sepkoski commented to us that our current reclassification of one group of organisms would require them to completely revise their results for this group. In almost every group of [fossil] organisms the number of described genera has doubled or more in the past 20 years. Use of the older literature, including the Treatise volumes, thus is hazardous without first hand knowledge of the organisms concerned. Although there are real fluctuations in diversity, many specialists are not convinced of this 'cyclicity'."

Perhaps the largest discrepancy in the Nemesis hypothesis arises from an observational absence of binaries with solar-type primaries and orbital periods ≥ 0.3 Myr in other star systems[7,8]. The situation is complicated further by the fact that Alvarez and Muller's[9] approximately synchronous periodicity (with mass extinctions) of asteroid and/or comet impacts on Earth is poorly defined. Their 28.4 Myr impact cycle is derived from 11 craters with average age uncertainties spanning intervals of 14 Myr and ranging as high as 40 Myr. When only major impact events with age uncertainties ≤ ± 2 Myr are considered (Fig. 1), a

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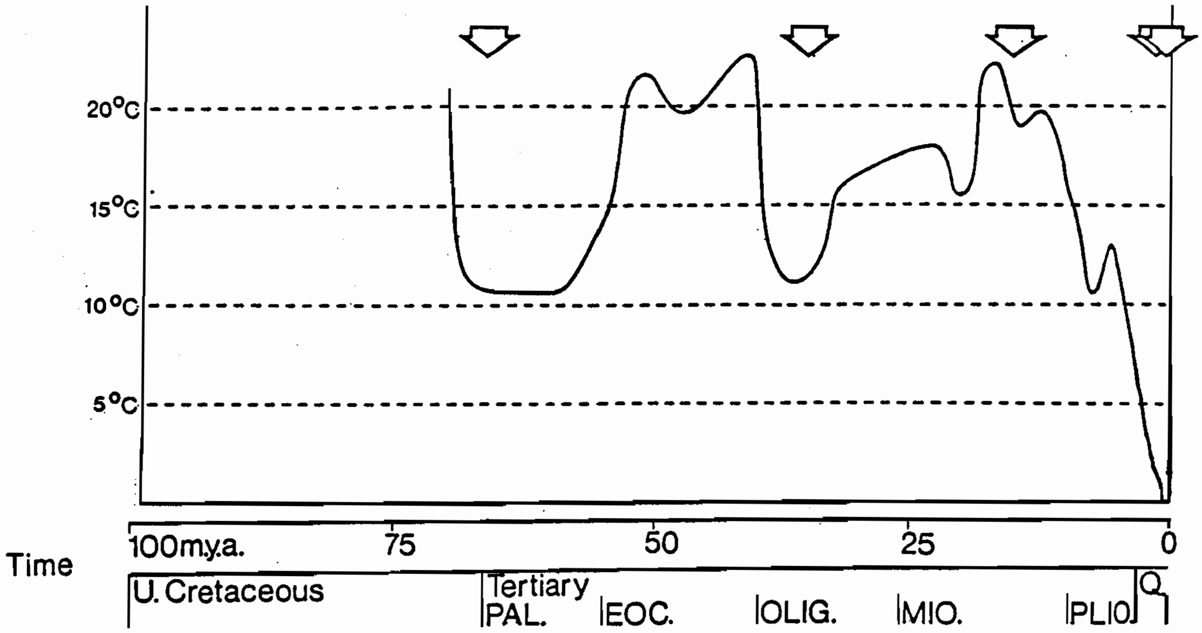

Fig. 1. Impact events resulting in craters > 10 km (dated by widespresd iridium enrichment and/or radiometrically dated impact melts). Arrows represent (from left to right), the 65 ± 2 Myr Ir anomaly[9], sanidine spherules[10] and impactite quartz[11], a 34.4 ± 0.6 Myr iridium anomaly and impact glass[12] (two separate impacts and a possible increase in the cosmic dust background[13]), Ries Basin and Moldau River impact glass (14.8 ± 0.7 Myr)[14], Ghana Crater and Ivory Coast impact glass (1.3 ± 0.05 Myr)[15], and Australian-Asian tectites (0.8 ± 0.03 Myr)[15]. Curiously, no mass extinctions are associated with the last two events. The solid line is the Cenozoic paleotemperature curve (New Zealand) which is reconstructed from changes in the diversity of planktonic foram species, oxygen isotope ratios, land plants and analyses of glacially derived ice-rafted sands in sub-Antarctic deep-sea cores.

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somewhat different picture emerges. The most precisely dated impacts are more consistent with the 33 ± 3 Myr periodicity of the sun's crossings through the galactic plane[16] (at least if the Ries Basin impact is regarded as part of the normal background). Note also that the solar system is presently in the galactic plane, that the probability of encounters with giant molecular clouds has thus increased, and that there have been at least two recent major impacts, which are consistent with Clube and Napier's[17,18] evidence for a recent tidal disturbance (≃ 5 Myr) of the Oort cloud.

Although these observations appear to support the galactic plane crossing hypothesis, Thaddeus and Chanan[19] argue that molecular clouds are not so tightly concentrated around the plane of the galactic disk that the probability of the sun encountering a cloud must decrease significantly at the amplitude of its oscillations above and below the plane (ie: The galactic hypothesis, too, may be in trouble).

Curiously, the most precisely dated impacts appear to be post-synchronous with climatic cooling (Fig. 1) and withdrawal of the seas from the continental shelves. It is possible that tectite formation and widespread iridium dispersal (via killing dust clouds) are inhibited by impact on deep water, and that the probability of recording such impact signatures increases as the probability of an incoming body striking land or shallow water ($\leq$ 50 m) increases, as when sea level falls and larger portions of the Earth's surface are exposed. In other words, the impact "cycle" in Fig. 1 may be more apparent than real - an artifact of climatic trends that, among other things, trigger extinctions (rather than the impacts being the primary cause of the extinctions). Though disappearances of certain planktonic foraminifera (but apparently not dinosaurs) are clearly associated with impact signatures, major crises in the history of life coincide more closely with climatic deterioration that often precedes the impacts[3,20,21,22,23]. Cyclic fluctuations of the solar constant[3] and/or the rate of mid-ocean spreading[24,3] may be the major causes of the critical deterioration. Perhaps, as Gould and I[25] have considered, impact events (whether cyclic or not) serve as amplifiers of deteriorations already in progress. Conversely, if an impact occurs during "stable" biological times, maybe no great decline of generic diversity will be recorded.

It begins to look as if pieces of the extinction puzzle can be assembled to produce many possible causes, and that more than one cause may be true.

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1. Weissman, P.R. Nature 312, 380 (1984).
2. Muller, R.A. et al. Nature 312, 380-381 (1984).
3. Pellegrino, C.R. & Stoff, J.A. Darwin's Universe: Origins and Crises in the History of Life, 158, 160-187 (Van nostrand Reinhold, New York, 1983).
4. Raup, D.M. & Sepkoski, J.J. Proc. Natn. Acad. Sci. U.S.A. 81, 801-805 (1984).
5. Sepkoski, J.J. & Raup, D.M. Dynamics of Extinction (ed. Elliot, D.) (Wiley, New York, in press).
6. Tappan, H. (personal comm., 1985).
7. Muller, R.A. & Pellegrino, C.R. (personal comm., 1984).
8. Clube, S.V.M. & Napier, W.M. Nature 313, 503 (1985).
9. Alvarez, W. & Muller, R.A. Nature 308, 718-720 (1984).
10. Smit, J. & Klaver, G. Nature 292, 47-49 (1981).
11. Bohor, B.F. et al. Science 224, 867 (1984).
12. Alvarez, W. et al. Nature 216, 886-888 (1982).
13. Pellegrino, C.R. Far Frontiers 1, (in press).
14. Grieve, R.A.F. Geol. Soc. Am. Spec. Pap. 190, 25-37 (1982).
15. Ganapathy, R. Nature 216, 885-885 (1982).
16. Rampino, M.R. & Stothers, R.B. Nature 308, 709-712 (1984).
17. Clube, S.V.M. & Napier, W.M. Mon. Not. R. astr. Soc. 208, 575-588 (1984).
18. Clube, S.V.M. & Napier, W.M. Mon. Not. R. astr. Soc. 211, 953 (1984).
19. Thaddeus, P. & Chanan, G.A. Nature (in press).
20. Archibald, J.D. Nature 291, 650-651 (1981).
21. Hickey, L.J. Nature 292, 529-531 (1981).
22. Clemens, W.A., Archibald, J.D. & Hickey, L.J. Paleobiology 7, 293 (1981).
23. Pellegrino, C.R. Time Gate (TAB, Blue Ridge Summit, Pa. 17217, 1985).
24. Hallam, A. A. Rev. Earth Planet. Sci. 12, 205 (1984).
25. Gould, S.J. & Pellegrino, C.R. (personal comm., 1980, 1984).