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EXTINCTION OF DINOSAURS: A POSSIBLE NOVEL CAUSE

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ABSTRACT

A novel cause of mass extinction of fauna close to the (K/T) Boundary is suggested. A large amount of non-protein amino acids (AIB and ISOVAL) has been observed close to this event. It is speculated that these amino acids may be toxic and are responsible for the extinction. The toxicity level is estimated for this suggestion to be true and experimentalists are encouraged to test this level of toxicity for the amino acids.

INTRODUCTION

The evidence for the extinction of more than half of all living species, both flora and fauna including deep-sea plankton and dinosaurs, at a time close to (K/T) Boundary is incontrovertible /1/. While extinctions are a common feature of the geological past, the extinctions near the (K/T) Boundary represent the most dramatic such episode in the past 150 million years. The identification of unusually high levels of the rare element, Iridium /2,3/, in sediments corresponding to the (K/T) Boundary at about 65 million years stimulated the hypothesis of the sudden impact of an extra terrestrial impactor as a cause for at least some of the observed extinctions /4/. However, the identification of two possible killer craters in Iowa and Yucatan /5/ has opened up the possibility of multiple impacts /5,6/, the source of which is supposed to be a giant comet that broke up and then pummelled the Earth with its debris for many years /7/. However, the actual mechanism by which the extinction occurred is shrouded in mystery. There are several speculations: e.g. a direct hit wiping out species due to the sheer energy of the impact /2/, acidic rainfall /8/, widespread darkness due to particle opacity leading to dramatic cooling of the atmosphere /3,6/, (iv) widespread forest fires /9.10/ and the catastrophic collapse of eco systems /11/. Here we add to this list a further speculation, namely, a possible poisoning by extraterrestrial non-biological amino acids. This would account for the observed pattern of extinction over an extended epoch /12-14/.

OBSERVATIONAL DATA

Large amounts of apparently extraterrestrial amino acids have indeed been found in the rocks close to the (K/T) Boundary Layer at Stevns Klint, Denmark /15/. A sketch of the site of Stevns Klint, detailing the depths from which samples have been taken for amino acid analysis, is shown in Fig.1. The observed abundances, as a function of distance from (K/T) boundary layer, of two amino acids, α-aminoisobutyric acid (AIB) and isovaline (ISOVAL), which are very rare on Earth, along with the abundances of rare element Iridium are shown in Table 1. It is very clear from a look at Table 1 that no amino acids are found at the boundary layer itself where a huge amount of iridium has been found. This gives us a clue as to the nature of the impactor. Zahnle and Grinspoon /7/ have considered how cometary debris would serve as carriers of organic molecules, while the core may be rich in iridium. Amino acids arriving in sub-cometary lumps would be burnt up in the atmosphere or on explosive impact, while Iridium will survive. But comets emit masses of small particles, when warmed in the inner solar system. This cometary dust is gradually decelerated in the Earth's upper atmosphere, heated relatively little if smaller than 50 μm and drifts down gradually to the surface. The time scale for sweeping up such cometary meteoroids is 1,000 years or more, while a comet can survive some 20,000-30,000 years against ejection by gravitational perturbations /16/.

It seems most probable that the two amino acids discovered near the (K/T) Boundary were amongst a much wider suite of cometary organics to land on the Earth but were not of benefit to biological systems. Indeed well over 70 amino-acids have been discovered in the organic material of the Murchison Meteorite /17/. Some of the prominent ones are displayed in Table 2. A host of aromatic and aliphatic structures were discovered by 'in situ' studies of dust from Halley's comet /18/. Unfortunately the techniques for mass spectrometry of the Halley dust was destructive, so we remain ignorant of the actual material, the data being compatible with a wide range of amino acids.

AMINO ACID POISONING

The speculative suggestion here is that if some of these amino acids are as poisonous as terrestrial toxins are known to be, then a case can be made for the demise of fauna due to amino acid poisoning. To validate the above suggestion, it is necessary to investigate (i) the process of uptake of non-biological amino acids in living organisms, (ii) the action of these non-protein amino acids on living organisms, (iii) the range of acquisition, and (iv) possible mechanisms of build up of resistance to toxic effects.

TABLE 1 IRIDIUM AND EXTRATERRESTRIAL AMINO ACIDS IN K/T BOUNDARY SEDIMENTS AT STEVNS KLINT, DENMARK

Sample in relation to K/T boundary	Ir ($ng\ g^{-1}$)	AIB ($ng\ g^{-1}$)	ISOVAL ($ng\ g^{-1}$)
+2.7m	0.01	<0.2	<0.2
+1.2m	0.01	<0.2	<0.2
+0.3m	0.4	200	50
K/T	87	<0.2	<0.2
-0.5m	0.03	350	120
-1.0m	0.03	37	20
-2.2m	0.03	<1	<1
-2.6m	0.03	<0.2	<0.2
-4.4m	-	<0.2	<0.2
-5.4m	-	<0.2	<0.2

TABLE 2 AMINO ACIDS IN MURCHISM METEORITE

Protein Amino Acids	Non protein Amino Acids
Glycine	N-methylglycine
Alanine	β alanine
Valine	N- methylalanine
Proline	N-ethylglycine
Glutamic Acid	α-aminoisobutyric acid (AIB)
	α-amino-n-butyric acid
	β-amino-n-butyric acid
	β-aminoisobutyric acid
	γ-amino-n-butyric acid
	Isovaline (ISOVAL)
	Norvaline
	Pipecolic acid

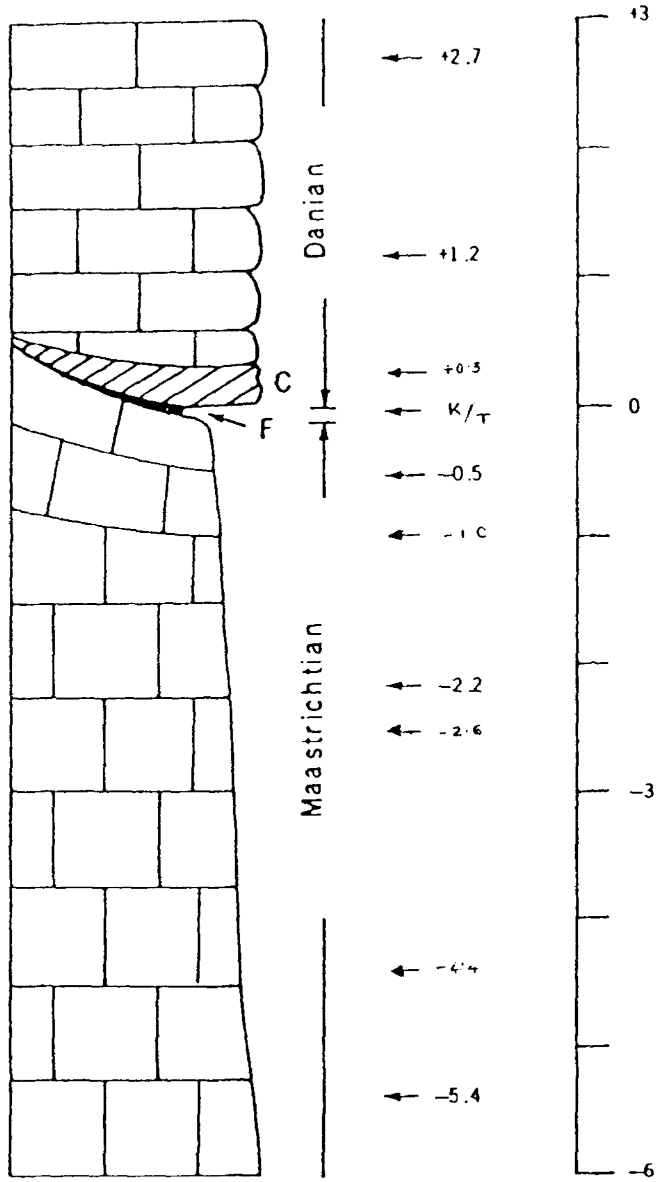

Fig.1 Stratigraphic section at the site Stevns Klint, Denmark. In left section structures C denotes Cerithium limestone and F denotes fish clay. The various geological stages are indicated, with (K/T) boundary denoted clearly. The depths from (K/T) boundary from which samples have been analysed are indicated by the arrows followed by the number in metres. The scale in metres from the (K/T) boundary is given in the right section. (Adapted from 13/)

While deposition of non-toxic or mildly-toxic compounds could have resulted in gross dietary imbalances with insidious deleterious effects; highly poisonous compounds may have had immediately disastrous consequences. In lower organisms and plants, direct non-specific absorption from solution may have provided a major route of intake into the food chain, whereas for animals, ingestion with water or food, or inhalation of fine dust would have occurred. 'Balanced' media are required for optimal microbial growth and imbalance leads to diminished growth rates and yields /19/. In animals the adverse consequences of antagonism between naturally-occurring amino acids and the inhibition of utilisation of L-amino acids by their enantiomorphs /20/ have been known for many years, and some analogues (e.g. ethionine, the S-ethyl analogue of methionine /21/) are highly toxic for a wide variety of species. Symptoms of antimetabolite action in mammals include loss of appetite and retarded growth /22/. Reduced food intake results in decreased protein synthesis, increased degradative metabolism, elevated blood urea levels, antagonism of intestinal amino acid transport, and excretion of amino acids /23/.

This brings us to the question of estimating toxicity of amino acids. Since none of the data is available, we make reasonable estimates, if our hypothesis of amino-acid poisoning is true. Zhao and Bada /15/ have estimated the amount of amino acids deposited in the layers close to the (K/T) Boundary as 5×10^{-5}g.cm^{-2} . This is a lower limit as it is the persistent residue of a much larger part of organic compounds brought in by the cometary dust. The period of deposition is estimated /7/ to be 20,000 to 100,000 years, so we take a mean of 50,000 years. Another important period is the time of accessibility in soils or decaying and living biota, before being transported away and laid down in sediments. We adopt a period of 100 years for this. The biologically active mass on the Earth's /24/ current major ecosystems averages 1.4 g.cm^{-2}. Thus the mass fraction of two poisonous amino acids is $\sim 10^{-7}$. It is suggested that this mass fraction is sufficient to give antimetabollic effects above.

CONCLUSION

From the foregoing discussion it is clear that amino-acid poisoning of many species, 65 million years ago, is not an unreasonable speculation. It should encourage biologists and biochemists to seek the relevant experimental data and information of the non-biological organics on metabolism. It is very important to investigate the biological effects of ISOVAL as well as other amino acids in detail.

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REFERENCES

1. Raup, D.M & Sepkoski (Jr), J.J. *Science* **215**, 1501-1503 (1982); McLaren, D.J. and Goodfellow, W.D. *Ann.Rev.Earth Planet.Sci.***18**, 123-171 (1990)
2. Alvarez, L.W., *Proc.Nat.Acad.Sci*, USA **80**, 627 (1983)
3. Alvarez, L.W., Alvarez, W & Asaro, F.*Science* **208**, 1095-1108 (1980)
4. Sheehan, P.M.Fastovsky, D.E.,Hoffman, R.G.,Berghams, C.B. & Gabriel, D.L. *Science* **254**, 835-839 (1991)
5. Shoemaker, e.quoted in Kerr,R.A. *Science* **255**, 160-161 (1992)
6. Wolfe, J.A. *Nature* **352**, 420-423 (1991). See the discussion in *Nature* **356**, 295-296 (1992)
7. Zahnle, K.R.Grinspoon, D. *Nature* **348**, 157-160, (1990)
8. McKinnon, W.B. *Nature*, **357**, 15-16 (1992)
9. Wolbach, W.S. Lewis, R.S & Anders, E.*Science* **230**, 167-170 (1985)
10. Wolbach, W.S., Gilmoor, I., Anders, E., Orth, C.J. & Brooks, R.R. *Nature* **334**, 665-660 (1988)
11. Sleep, N.H, Zahnle, K.J., Kasting, J.S. & Morowitz, H.J. *Nature* **342** 139-142 (1989)
12. Hickety, L.J. *Nature* **292**, 529-531 (1981)
13. Archibald, J.D & Clemens (Jr), W.A. *Am.Sci.* **70**, 377-385 (1982)
14. Officer, C.B., Hallam, a., Drake, C.L. & Devine, J.D. *Nature* **326**, 143-149 (1987)
15. Zhao, M. & Bada, J. *Nature* **339**, 463-465 (1989)
16. Fernandez, J.A. & Ip, W.H. *Icarus* **54**, 377-387 (1983)

17. Cronin, J.R., Pizzarello, S.B. Cruikshank, D.P. in *Meteorites and the Early Solar System* (eds.Kerridge, J.F & Matthews, M.S.), 819-857 (University of Arizona Press, Tucson, 1988)

18. Brownlee, D.E. & Kissel, J. in *Comet Halley* **vol.2** (ed.J.Mason), 89-98 (Ellis Horwood, Chichester, UK 1990)

19. Halvorson, H.O and Spiegelman, S. *J.Bacteriol.* **64**, 207-222 (1952)

20. Fox, S.W.,Fling, M & Bollenback, G.N. *J.Biol.Chem.* ***155***, 465-468, (1964)

21. Dyer, H.M. *J.Biol.Chem.* **124**, 519-524 (1938)

22. Snell, E.E. & Guirard, B.N. *Proc.Natl.Acad.Sci. US* **29**, 66-73 (1943)

23. Kumta, US & Harper, A.E. *J.Nutr.* **74**, 139-147, (1961)

24. Bolin, B. in *the Greenhouse Effect, Climatic Change & Ecosystems, Scope* **29** (eds:B.Bolin et al) 93-155 (John Wiley, New York, 1986)