Antarctic ice sheet[4] has been under investigation by Hughes, Denton and others as part of the CLIMAP experiments[5]. Results of their analysis were presented during the Symposium on the Dynamics of Large Ice Masses, held in August 1978 at Ottawa; where a review of our work was also presented.

We wish to acknowledge the work of Denton, Hughes and their colleagues concerning the Pine Island and Thwaites glaciers, and we do not claim priority in recognizing the existence of these glaciers, their importance as calving bays, and the possibility that they may currently be "surging".

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## Terminal Cretaceous catastrophe

THE statements of Smit and Hertogen[1] that the terminal Cretaceous extinctions were "extremely abrupt" (~200 yr), lacked "warning signal," and that "gradual extinction lose their credibility on more detailed inspection," require substantiation. Simultaneous geological-range terminations of numerous taxa in a stratigraphic section usually indicate a hiatus (missing strata). A terminal Cretaceous marine shallow-water $CaCO_3$ dissolution event is noted at most marine localities. Was it not operative at Caravaca? Such an event would have caused a terminal Cretaceous hiatus that, in itself, could have accounted for the simultaneous termination of ranges in the Caravaca section, creating the illusion of catastrophic extinctions. Certainly, the termination of ranges via a hiatus would lack a 'warning signal'. Until it is proved that a terminal Cretaceous hiatus does not exist in the Caravaca section, claims of a terminal Cretaceous 'catastrophe' cannot be accepted.

An instantaneous catastrophe phenomenon such as a meteorite impact would have caused synchronous land and marine extinctions. Smit and Hertogen's claims of "near synchronous extinction" conflicts with Butler *et al.*[2] and Lindsay *et al.*[3] who cast serious doubt on any simultaneity. The statement "the independence of the event from the known normal environmental processes going on in the latest Cretaceous", is unfounded; Smit and Hertogen fail to consider the global warming of deep and shallow marine waters across the Cretaceous–Tertiary boundary noted by Boersma *et al.*[4] and Margolis *et al.*[5] They also fail to explain why only planktonic $CaCO_3$-producing marine organisms were affected significantly by the extinctions. Our Cretaceous–Tertiary dinoflagellate studies along the eastern US—even across a terminal Cretaceous hiatus—record no notable terminal Cretaceous extinctions. Clearly, oceanic *p*H changes seem to have been a factor in the marine extinctions.

Smit and Hertogen have failed to integrate significant aspects of the geobiological record into their extraterrestrial extinction model. As such, their use of the term "holocaust" for the terminal Cretaceous extinctions is inappropriate.

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SMIT AND HERTOGEN REPLY—The hiatus assumed by McLean is the least likely explanation for extinctions at the Cretaceous–Tertiary boundary. McLean is confusing the sequence of the thermal events at the boundary and fails to consider the iridium peak, important evidence which we used to postulate a catastrophic (meteoritic) event.

McLean's postulated hiatus would have to be quite large to make it worldwide, and to let it wipe out any geochemical or other 'warning signals'. If such a large hiatus were operative, other taxa like benthic foraminifera and dinoflagellates should reflect a similar "illusion of catastrophic extinction", which is not the case. Further, the expected residual clay deposit from a dissolution event is not present either; a dissolution of the topmost 100 m of the Cretaceous at Caravaca would leave a 20-m thick clay deposit, but only one species would be added to the total of 55 planktonic species that became extinct. We have argued previously[1,2] that all stratigraphic subdivisions known to be connected with the boundary are present at Caravaca, including an additional interval, without signs of a hardground or dissolution. McLean needs to prove that a hiatus is present at Caravaca.

While synchronism of extinction is difficult to confirm, the results of Butler *et al.*[3] and Lindsay *et al.*[4] have been seriously questioned[5–7]. McLean also does not mention a similar magnetostratigraphic investigation by Lerbeckmo *et al.*[8,9], who favour synchronism. The problem has not been satisfactorily resolved and a claim of diachronism cannot yet be accepted.

The independence of the event from the normal environmental processes going on in the latest Cretaceous is inherent in the model and it certainly deserves further testing. McLean, however, is confusing cause and effect of the Cretaceous–Tertiary boundary event, when he brings a 'global warming' into the discussion as a normal terminal Cretaceous process. Data of Boersma *et al.*[10] and Margolis *et al.*[11] which indicate a warming, are exclusively Palaeocene and postdate the event. Rather a slight cooling is observed from the Cretaceous data only. The 'global warming' of Margolis *et al.*[11] indicates that the Cretaceous–Tertiary boundary occurred within a period of high global temperatures, lasting ~40 Myr from mid-Cretaceous to Lower Eocene, but as such there is no reason to relate these to the Cretaceous–Tertiary boundary event.

Lowermost Palaeocene warming[12] may well be a consequence of a large impact; either by direct heat generation or by a sort of 'greenhouse effect' (following oceanic impact) much in the same way as in the model of Alvarez *et al.*[13]. Dinoflagellates may escape the supposed suppression of sunlight by their cyst-forming abilities, as well as the dinoflagellate-like, $CaCO_3$ producing nannofossils *Braarudosphaera* and *Thoracosphaera*. However, we agree that the biological consequences of a very large impact are largely speculative at the moment.

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