

## Discussion

# COMMENTS ON WOLFE AND UPCHURCH (1987): NORTH AMERICAN NONMARINE CLIMATES AND VEGETATION DURING THE LATE CRETACEOUS

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Wolfe and Upchurch (1987) have undertaken a comprehensive analysis of the North American palaeofloristic data bearing on the interpretation of the Late Cretaceous climates. A broad picture emerges from this work, with the temperature lows at about the Albian/Cenomanian boundary and in the Maastrichtian, and the major rise in the mid-Senonian, in good agreement (though not admitted by the authors) with the results obtained from the Asiatic palaeofloristic succession (Krassilov, 1975). However, there are differences stressed by Wolfe and Upchurch. Considering the Asiatic Late Cretaceous they stated (p. 59): "Krassilov suggested that the Campanian was the warmest part of the Late Cretaceous whereas Vakhrameev suggested that the Santonian was the warmest". Their own "interpretations" seem to support Vakhrameev (Santonian peak) against Krassilov (Campanian peak). Actually in the paper they cited, Vakhrameev (1978, pp. 13–14) wrote (my translation from the Russian): "Comparing the floras of which the remains occur in various stages of the Late Cretaceous, we can note considerable warming in the Campanian which was indicated earlier by V. A. Krassilov (1975)". Further, he gave additional evidence for the Campanian warming worldwide. I could not find a passage which could give Wolfe and Upchurch the notion of a controversy between Vakhrameev and Krassilov on this particular

point. In addition the original interpretations by Wolfe and Upchurch based on the North American Santonian/Campanian floras are dubious. A comparatively complete floristic succession through this time interval exists only in the southeastern part of North America. With reference to Table V, they stated that "the Campanian appears to have been slightly cooler than the Santonian" (p. 44). Actually the entire leaf-margin percentage — a major temperature indicator — is 84 for a single Santonian locality Severn River, while for the four Campanian localities Grove Point, Gay Head, Middendorf and Coffee Sand the values are 94, 82, 83 and 85 respectively, with an average for the Campanian of 86. Neither the absolute figures nor the average support the above conclusion by Wolfe and Upchurch. Rather they are in agreement with my suggestion of a peak warming in the Campanian.

Further, and probably more important, is the discussion of the late Maastrichtian temperatures. I suggested a decrease in the late Maastrichtian as compared with the Campanian, the cooling being further accentuated at the Cretaceous–Tertiary boundary (Krassilov, 1975 and elsewhere). Commenting on this point, Wolfe and Upchurch stated (p. 59): "However, the age of the Krassilov's late Maastrichtian assemblage is not well controlled (the assemblage comes from beds that rest on marine late Maastrichtian beds), and

thus Krassilov (1975) could have compared valid Campanian assemblages with early Paleocene assemblages, a comparison that can lead to highly erroneous conclusions regarding temperature changes". I object to this statement because the assemblage in question came from paralic beds resting conformably on *Pachydiscus* beds of the lower Maastrichtian. The composition of the assemblage containing abundant *Nilssonia* and a bennettite *Pterophyllum* is rather typically Senonian and the above tuffaceous beds still contain occasional *Nilssonia* as well as various ferns indicating a "fern spike" noticed by several workers above the Ir anomaly layer in American sections. In other words, the assemblage assigned to the Late Maastrichtian is bracketed between the marine lower Maastrichtian and the continental beds which cannot be younger than lowermost Palaeocene. As for the North American data, the interpretations by Wolfe and Upchurch are again curious. The Late Maastrichtian assemblages came from the Western Interior where a few Campanian floras are known. For the uppermost of these, Fruitland, the entire leaf-margin percentage is 76 while for the Late

Maastrichtian Vermejo, Lower Raton, Laramie and Littleton they are respectively 71, 72, 71 and 71, and for the Lance, Hell Creek and other localities a few degrees to the north, figures as low as 62 and 58 are given in Table IX. These values can hardly warrant the conclusion that "In the Western Interior the late Maastrichtian was warmer than the Campanian" (p. 48 and repeated several times elsewhere). Both Asiatic and North American data, taken as they are, suggest a broad low of the generalized temperature curve at K/T rather than a broad rise with a short "excursion" envisaged by Wolfe and Upchurch.

### References

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## REPLY

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We agree with Krassilov that our (1987b) data and interpretations of Late Cretaceous nonmarine climates in North America are generally in accord with conclusions reached by him (1975) and Vakhrameev (1978) based on Asian floras. We regret, however, that Krassilov feels that we did not admit to this. In the paragraph that was started with references to the works of our Russian colleagues cited

above, we (1987b, p. 59) concluded: "...our interpretations [of the North American assemblages] strongly support the overall conclusion that the warmest part of the Late Cretaceous was approximately in the middle of that time interval."

Differences remain, however, between Krassilov and us regarding: (1) whether the Campanian was warmer than the Santonian, and