

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 *Nilssonina* and a bennettite *Pterophyllum* is rather typically Senonian and the above tuffaceous beds still contain occasional *Nilssonina* 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.

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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

(2) temperature trends in the Maastrichtian–Paleocene interval. As Krassilov suggested, the second issue is more significant and will be discussed first.

Krassilov's (1975 and above) thesis of a gradual temperature decline of the post-Campanian is based on a sequence of floras inferred to be of late Maastrichtian to earliest Paleocene ages. However, the only independent chronological evidence is that this sequence rests conformably on Maastrichtian *Pachydiscus* beds, and time continuity with the early Maastrichtian does not necessarily follow from this stratigraphic relation. A good example of this phenomenon is the Senonian through Paleocene sequence in the San Juan Basin of New Mexico, which was long thought to represent continuous deposition. Recent paleomagnetic and radiometric data indicate that almost all the Maastrichtian and some of the lower Paleocene is missing between the early Maastrichtian marine beds and early Paleocene continental beds, despite an apparently conformable relation (Fassett and Obradovich, 1986).

Krassilov attempts to reinforce his limited marine evidence by citing that (1) his late Maastrichtian paralic beds contain abundant

extinct cycadophytes and (2) his earliest Paleocene tuffaceous beds contain "various ferns", which he correlates with the North American fern spike immediately above the iridium anomaly at the Cretaceous–Tertiary boundary. We are puzzled as to why the occurrence (even abundantly) of extinct cycadophytes is taken as absolute proof of Maastrichtian age for his lower assemblage, because Krassilov notes that his earliest Paleocene flora also contains an extinct cycadophyte.

Regarding Krassilov's "fern spike," we consider the equation of this to the North American fern spike in the basal Paleocene to be fanciful at best. In North America, the fern spike is confined to <1 m above the Ir anomaly. The flora is highly depauperate, with only three fern palynomorph taxa (Tschudy et al., 1984) and one or two fern-leaf taxa (Wolfe and Upchurch, 1986, 1987a). Fern-dominated megaflores are not restricted to the basal Paleocene, and ferns occur abundantly and diversely higher in the North American Paleocene (Brown, 1962). The fact that fern-dominated megaflores can characterize tuffaceous units of Late Cretaceous age (e.g. Andrews and Pearsall, 1941; Rushforth, 1971) suggests that the apparent abundance of ferns in Krassilov's

TABLE I

Leaf-margin percentages standardized to paleolatitude 40°N for North American Santonian, Campanian, and Maastrichtian assemblages from low–middle paleolatitudes. Used for standardization is a leaf-margin gradient of 1.2%/1° latitude (Wolfe and Upchurch, 1987b, pp. 57–58).

Age	Assemblage	Entire (%)	Paleo-latitude	At 40°	Average
Latest Maastrichtian	Littleton	71	48°	81	80
	Lower Raton	72	46	79	
Early late Maastrichtian	Laramie	71	48	81	80
	Vermejo	71	46	78	
Early Maastrichtian	Perry Place	69	37	65	62
	Cooper Pit	62	37	58	
Late Campanian	Fruitland	76	38	74	72
	Coffee Sand	85	29	72	
	Middendorf	83	28	69	
Earliest Campanian	Gay Head	82	33	74	70
	Adaville	62	43	66	
Santonian	Grove Point	94	30	82	77
	Severn River	84	30	72	

tuffaceous rocks may simply reflect lithofacies. Lacking evidence that his "fern spike" (which is not typical of the North American fern spike) closely followed an Ir anomaly (and/or associated shock-metamorphosed minerals) makes more than dubious Krassilov's statement that his "fern spike" beds "...cannot be younger than lowermost Paleocene." Simply put, Krassilov's post-Campanian floral sequence has poor independent age control.

We (1987b) concluded that temperature sharply declined into the early Maastrichtian, rose again prior to the Cretaceous-Tertiary boundary, and continued to warm into the early Paleocene, conclusions that parallel Boersma's (1984) oxygen-isotope analyses from deep-sea samples. Additionally, we (1986, 1987a) inferred a brief low-temperature excursion at the boundary. Krassilov, however, attempts to dispute our post-Campanian temperature trends by (1) using only part of our data set and (2) failing to factor in relative paleolatitudes. The coolness of the early Maastrichtian relative to the Campanian and late Maastrichtian is clearly evidenced by percentages of entire-margined dicotyledonous species (if standardized for paleolatitude as in Table I), with high percentages generally indicative of higher temperatures (as Krassilov agrees). The data set used in Table I has independent age controls from a variety of geologic data: marine invertebrates, vertebrates, paleomagnetic chronology, radiometrics, and stratigraphy relative to the Ir anomaly.

Finally, which was the warmest, the Santonian or the Campanian? Table I indicates, as we (1987b) previously concluded, that the Campanian was "slightly" cooler than the Santonian (Krassilov erroneously considered the Grove Point assemblage as Campanian, and we can see where a cursory examination of our (1987b) Table IV might have led him to this conclusion). Although we do not consider the

present data to be absolutely conclusive, they do suggest a thermal maximum near the Santonian-Campanian boundary, with a second thermal maximum at the end of the Cretaceous.

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