# Reply to 'Coal geology affects nutrient diffusion modelling in the prehistoric record'

To the Editor — Edwards[1] notes that the difference in rank between Cretaceous and Carboniferous coal will impact the mobilisation of alkaline earth metals (calcium and magnesium) and alkali metals (potassium). The author also describes two additional hypotheses to explain changes in sulfur and phosphorus abundances between the two periods. These are valid hypotheses, but Occam's razor suggests that a single explanatory hypothesis (the presence of large tetrapod herbivores versus no tetrapod herbivores) that can explain all the results is better than three separate hypotheses (as suggested by Edwards).

Also, the key finding in my paper[2] was that tetrapod herbivores led to the more even distribution of elements in the Cretaceous versus the Carboniferous (a finding that was not challenged in the Comment). A greater abundance of elements is not always beneficial to ecosystems (as eutrophication demonstrates), but a more even distribution of nutrients (leading to fewer nutrient-limited ecosystems) generally is.

There is likely truth to all hypotheses put forth by Edwards and myself, and further research is necessary to distinguish which among them are correct. The author makes excellent suggestions of future potential comparisons of low-rank Carboniferous coals in Russia and Ukraine to low-rank US Carboniferous coals. He also suggests further empirical studies of how large herbivores transport nutrients in Indonesian raised bogs.

The author also proposes that other elemental transport mechanisms be examined, such as fire or flying insects. Palaeo-climate simulations[3] suggest there were relatively similar temperatures in the two coal-producing regions (8–16 °C in the Cretaceous versus 15–20 °C in the Carboniferous; see Supplementary Table 3 in ref. [2]), which (all else being equal) may suggest relatively similar fire frequencies between the two periods. Therefore, I do not believe differences in fire prevalence can explain my paper's results. Flying insects could clearly move significant concentrations of nutrients, and their role needs to be better examined[4], but previous work suggests that nutrients moved through feces are several orders of magnitude more important than those transported by bodies (such as through insects)[5]. Small animals, like flying insects, also tend to be predator controlled, thus keeping populations (and nutrient distribution potential) in check, while megaherbivores tend to have few predators, creating the potential for very high population densities (and nutrient distribution)[6]. Also, flying insects tend to be wind dispersed, and their nutrient dispersal patterns tend to reflect abiotic patters (like dust) instead of diffusion.

Finally, potassium did not have higher concentrations in the Cretaceous versus the Carboniferous like all the other plant-important nutrients examined in ref. [2]. I hypothesized that potassium is depleted in animals through a faster mechanism than the other plant-important nutrients. Edwards mentions that potassium is abundant in animals. However, my point was not that animals do not have potassium, but that sodium is not wanted in abundance by plants, yet most animals obtain sodium from the consumption of plants[7]. This seems evolutionarily unstable and may have differed in the past, with different rates of recycling of potassium and sodium between animals and plants. However, further research is needed to understand this result as well. ❐

Christopher E. Doughty
*School of Informatics, Computing, and Cyber Systems, Northern Arizona University, Flagstaff, Arizona, USA.*
*e-mail:* chris.doughty@nau.edu

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## Competing interests

The author declares no competing interests.