Strontium isotopes within multi-isotope approaches to ecological and paleoecological research: A case study tracking the movement and feeding ecology of a 17,000-year-old woolly mammoth

There has been an exponential increase in applications of stable isotope ratios of carbon, nitrogen and oxygen in ecological and paleoecological research. More recent advances have included isotopic analyses of individual compounds, such as fatty acids and amino acids. Some researchers consider that we are now entering a ‘golden age’ of applying strontium isotope ratios alongside these more ‘traditional’ light isotope approaches within isotope ecology. I will present a case study employing strontium isotopes within a multi-isotope approach to examine the feeding ecology and movement of an ancient woolly mammoth (*Mammuthus primigenius*) from Arctic Alaska. Alaska is experiencing rapid environmental changes in response to recent warming. Radical environmental changes also occurred during and after the last glacial maximum (LGM, ~21,000 years ago). During the LGM, this region was inhabited by a variety of now extinct megafauna, including the iconic woolly mammoth. What caused the extinctions of these ice-age megafauna is still hotly debated. Although the life of mammoths has sometimes been portrayed as including large seasonal migrations, this inference remains untested and is based on the behavior of extant proboscideans rather than on paleo-data. To gain insight into the life history of a mammoth from the Arctic, we longitudinally split the curved, 1.5-meter-long tusk of a bull mammoth using a band saw. The specimen is one of two tusks associated with a skull from a single individual found north of the Brooks Range above the Arctic Circle. Calibrated radiocarbon dates from both the skull and one of the tusks indicate this bull mammoth died 17,000 calendar years ago during the closing millennium of the LGM in this part of the Arctic. After sectioning the tusk to reveal annual growth bands, we used sequential samples taken from along the entire length of the exposed inner surface of the tusk for stable isotope analyses (N and C on the organic fraction and C and O on the inorganic fraction) as well as strontium isotope ratio (Sr$^{87}$/Sr$^{86}$) analysis in order to reconstruct the animal’s feeding ecology, environment, as well as its movements through the course of its life. This temporally precise, multi-isotope reconstruction is providing insight into the life history of a woolly mammoth between birth and death, including its diet, changing nutritional state, and geographic movement. Based on histological and seasonal isotopic oscillations, we estimate this mammoth was ca. 30 years old when it died and that he wandered extensively during several, multi-year periods of his life. Death seems to have followed an extended period of starvation. I will close by briefly providing examples of the wide array of other applications of strontium isotopes in ecological and paleoecological research.