The development of Neogene grasslands in relation to climate and atmospheric CO_2: The carbon isotope ratios of fossil phytoliths

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The biogeographic distribution of C_3 and C_4 grasses results from the interplay between atmospheric CO_2/O_2 ratios and climatic factors such as temperature, amount and season of precipitation. Reconstructed shifts in the proportion of C_3 and C_4 grasses in the Neogene (Miocene and Pliocene) provide insight into the complex environmental dynamics that have influenced the biogeography of grasses in the past, and the likely responses of grasslands and croplands to future global changes. Although different methods have been used to reconstruct the photosynthetic pathway of vegetation (i.e. tooth enamel $\delta^{13}C$, soil carbonate $\delta^{13}C$), none of these proxies provide a record of C_3 and C_4 grasses specifically. On the other hand, the $\delta^{13}C$ of organic matter trapped in grass phytoliths (microscopic silica bodies produced by grasses) provides a direct record of the C_3/C_4 of grasses rather than the C_3/C_4 of overall vegetation. As a result, this method can detect pure C_3 grasslands as distinct from other C_3 ecosystems such as woodlands or forests.

The $\delta^{13}C$ signatures of Neogene fossil phytoliths from the central Great Plains, USA, indicate a strong trend from 0% C_4 grasses (100% C_3) at around 8.5 Ma to over 80% C_4 grasses by 3 Ma. The previously identified shift from a C_3 to C_4 diet recorded in the $\delta^{13}C$ of herbivore tooth enamel at around 7 Ma in North America (Wang et al., 1994) was in fact a shift from C_3 grasses to C_4 grasses rather than from C_3 shrubs/trees to C_4 grasses. These data reveal the presence of mid-latitude pure C_3 grasslands at 8.5 Ma, an ecosystem unlike any found today. The proportion of C_4 grass 3-4 Ma (84%) is much greater than modern proportions in northern Nebraska (50%), suggesting that the early Pliocene warming favored C_4 grasses. These results provide the first direct record of changes in the dominant photosynthetic pathway of Neogene grasses.

Wang, Y., Cerling, T.E., and MacFadden, B.J. 1994. *Palaeogeography, Palaeoclimatology, Palaeoecology* 107: 269-279.

Geochemistry of abyssal peridotites from Gakkel Ridge, Arctic Ocean

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Gakkel Ridge, the slowest spreading mid-ocean ridge in the world, has a unique constellation of low melting degree peridotites and basalts. Peridotites made up nearly a quarter of all rocks recovered on Gakkel Ridge during the AMORE 2001 expedition. Thousands of hand samples and approximately 150 thin sections of peridotite were studied while still at sea. These studies showed that the Gakkel Ridge peridotites are as a group relatively fertile. The most fertile samples lay within the nearly 100 km truly amagmatic portion of the ridge at 3°E. Despite the relative fertility of these samples, no evidence was seen of mantle veining.

Chrome spinels from the peridotites have generally low chrome numbers, with a minimum of .11 and a mean of about .17 in the amagmatic zone. The chrome numbers measured correlate well with the HREE, showing that the linkage of major elements and moderately incompatible trace elements in abyssal peridotites functions also at very low degrees of melting. In general the REE are relatively flat to moderately depleted, suggesting a relatively small degree of depletion. In contrast to samples from other ridges, none of the samples had evidence of MREE depletion that might indicate melting in the presence of residual garnet. Instead, the residual peridotites appear to be formed by varying degrees of melting in the spinel lherzolite facies.

To the east of the amagmatic section, increasing magmatic activity is associated with a greater degree of depletion seen in both major and trace elements. Chrome numbers in this region range from .3 to as high as .63, the highest chrome number yet recorded on the ocean floor. After robust magmatism resumes east of 30°E, no outcrops of peridotite were found except for a single dredge haul at 70° E. This dredge haul had the lowest chrome number found in the region (.11), equal to the lowest anywhere in the world.

The change in the west from very fertile (amagmatic) to depleted compositions occurs abruptly at the edge of the amagmatic region, suggesting that crustal production and residual mantle composition are linked as on other mid-ocean ridges. The mechanism by which this sudden change occurs is however quite unclear. It is moreover difficult to envision how the few very depleted samples became so depleted given the overall fertile nature of the ridge and the low degrees of partial melting observed. It is likely that the highly depleted samples became that way prior to their arrival beneath Gakkel Ridge.