Global change in the late Miocene: terrestrial effects on the ocean carbon isotopic record

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Global terrestrial ecology underwent an important global change in the late Miocene to early Pliocene. In Asia, Africa, and North America C_4 ecosystems expanded and became a notable element of the global ecology during the period from 5 to 7 million years ago. This change is recorded in the isotopic composition of paleosols and in the isotopic composition of mammalian herbivore teeth. Notably, the change in diet does not correspond to the change in tooth height, or hypsodonty, that is generally assumed to mark the expansion of grasslands. However on each of these continents the late Miocene to early Pliocene was a period of important faunal change, each becoming having more species characteristic of open habitats. Today, and presumably since the late Miocene, savannas and tropical to temperate grasslands dominated by C_4 plants make up a significant fraction of the global biomass. Using the global distribution of terrestrial ecosystems and estimates of soil carbon, the pool of C_4 biomass is estimated to make up between 10 and 15% of the terrestrial carbon pool. Because C_3 plants have $\delta^{13}C$ values of about $-26‰$ compared to $-13‰$ for C_4 plants, this change at the end of the Miocene represents a real shift in the average isotopic composition of the terrestrial biomass.

At the same time the isotopic composition of dissolved inorganic carbon in the oceans changed by about 0.5‰ suggesting a change in the global carbon budget. Likewise the isotopic composition of detrital carbon in the Bengal fan recorded the isotopic shift on the continents indicating that the terrestrial carbon can have significant effects on the ocean carbon budget.

It is possible that the expansion of C_4 dominated continental ecosystems could significantly alter the amount of carbon in the terrestrial pool. Using biomass estimates and net primary production it is clear that the residence time of carbon in the terrestrial pools varies significantly with ecology: carbon in semi-desert and tropical savannas have carbon residence times less than a decade whereas xeric to tropical forests have carbon residence times measured in several to many decades. The question of what the savanna and other C_4-dominated ecosystems replaced is critical to the question of the shift of the isotopic composition of oceanic carbon. If these ecosystem with relatively short carbon residence times (including storage in soils) had replaced ecosystems with significantly longer residence times, then the terrestrial component of the isotopic shift of the oceans in the late Miocene is even larger. Shifts in the terrestrial carbon budget in the late Mioene to early Pliocene can account for 0.1 to 0.5‰ shift in the isotopic composition of the ocean.