# The importance of hickory trees (*Carya*) in biogeochemical cycling of meteoric $^{10}Be$

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Meteoric $^{10}Be$ is widely used to monitor weathering and erosion of soils, with little regard to biogeochemical cycling. We found that hickory trees (Carya spp.) strongly bioaccumulate beryllium. Because oak-hickory forests are a dominant biome over much of the eastern United States, hickory trees can play an inordinately large role in the cycling of meteoric $^{10}Be$ in these areas.

To explore the role of trees in biological cycling of $^{10}Be$, we analyzed composite samples of wood and leaves from four dominant tree species (red hickory, Carya ovalis; black oak, Quercus velutina; red maple, Acer rubrum; and tulip poplar, Liriodendron tulipfera) as well as soil at the Martel experimental forest in northern Indiana, USA. We analyzed samples from 1 ha of unmanaged forest growing on loess and loamy till of Late Wisconsinan age.

We found that hickory contains the highest beryllium concentrations by a factor of 50-100, with an average of 0.39 ppm (dry mass) in the wood, subequal to the average exchangeable [Be] in the soil of 0.43 ppm. Abscised hickory leaves have a higher [Be] of 2.0 ppm. The isotopic ratio $^{10}Be/^{9}Be$ in all four tree species was similar, ranging from $6\text{-}8 \times 10^{-9}$. Using standard allometric equations relating tree biomass to trunk diameter, and assuming that belowground biomass has the same [Be] as aboveground, we calculate that hickory trees at our site contain an average of ~0.5% of the total $^{10}Be$ under their crown and that 5-15% of this Be is cycled annually by leaf abscission. It is not clear at this point what fraction of Be in litterfall is recycled into the plant, returned to the soil, or carried to groundwater as organic complexes.

Although the fraction of $^{10}Be$ in standing biomass is small, annual cycling in litterfall can be significant when integrated over thousands of years. Using our values for [$^{10}Be$] in litterfall, we can estimate the probability that a given atom of $^{10}Be$ in a forest soil will have passed through a hickory tree. Hickories occupy an average of ~10% of the oak-hickory forest area. Assuming that trees are randomly distributed and that litterfall Be is returned to the soil, and maintaining a constant $^{10}Be$ budget for generality, we calculate that nearly half of all $^{10}Be$ in the forest soil will have passed through a hickory tree over the past 10 ky. It is clear that hickories can transport a sizable fraction of the total $^{10}Be$ in their nutrient cycle, and that they may be responsible for landscape-scale Be mobility.

Biogeochemical cycling of $^{10}Be$ has not previously been fully appreciated. It is known that many plants and fungi contain Be at the 0.1-0.5 ppm level (ash mass), approximately 10 times lower than in hickory, and that the larch tree (Larix) also accumulates Be. There has been no systematic survey, however, to examine $^{10}Be$ in the ecosystem. Much more work is needed to understand $^{10}Be$ mobility in the biosphere, including the influence of ecosystem shifts, land management, harvesting, and burning, both natural and anthropogenic. It is possible that $^{10}Be$ signals previously attributed to soil erosion may instead be due to biological disturbance.

# Weathering at the Mineral-Fungus-Bacteria Interface Analyzed with Scanning Electron Microscopy and Helium Ion Microscopy

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## Introduction and Methods

Bacteria and fungi are documented agents of chemical weathering and nutrient uptake by higher plants. However, the role of biofilm in these processes is poorly understood. This study examines components of a laboratory column growth experiment to study the mineral-fungus-bacteria interface, morphology of mineral surfaces, and associated microbes and biofilm when calcium and potassium sources are varied. We hypothesized that 1) under limiting Ca and K conditions, thick biofilm cover develops to protect the mineral-fungus-bacteria interface and facilitate direct cation uptake from the minerals; 2) as Ca and K are made increasingly available in the input solutions, biofilm becomes thinner, patchy and less developed.

Red Pine (*Pinus resinosa* Ait.) was grown in leach tubes filled with quartz sand and 0.5 wt% biotite and 1 wt% anorthite. Half of the trees were inoculated with *Suillus tomentosus* and a variety of soil bacteria and the other half were left without inoculation. Columns without biology served as controls. The columns were supplied with Ca and K in irrigation water at 0, 10, 30 and 100% of what a healthy tree would need for growth. A subset of columns were destructively sampled after one month and three months growth. Biotite and anorthite were analyzed from the rhizosphere of each tree and also from the bulk material with helium ion microscopy (HeIM) and scanning electron microscopy (SEM) equiped with energy dispersive x-ray spectroscopy (EDS).

## Results and Discussion

Microscopy images show that after one month, bacterial colonization dominated the rhizosphere with few areas of fungal development. By the 3$^{rd}$ month, abundant fungal hyphal cover of rhizospheric minerals developed in the 0 and 10% Ca and K treatments and the 30 and 100% Ca and K treatments remained less colonized. The bulk material of the tree treatments and the controls remained nearly unaffected by microbes. Fungal hyphae appear to "search" for weaknesses of the crystal structure such as particle and step edges, existing fractures and perhaps inpurities or inclusions. Bacteria are associated with fungal hyphae in some places, but do not form large biofilm colonies. Biofilm and polysaccharide cover remained patchy through the 3 month growth period in all treatments, but a slight decrease of cover was detected with increasing concentrations of Ca and K in the irrigation solutions.

In conclusion, our study shows that biofilm is directly affected by Ca and K concentrations in input solutions, but later time points of our experiments (6 and 9 months), most likely with more developed biofilm, will be analyzed to support our first hypothesis.