Geophysical Research Abstracts
Vol. 13, EGU2011-6751-1, 2011
EGU General Assembly 2011

Pedogenic carbonate recrystallization rates and periods are regulated by temperature-dependent rhizosphere processes: Relevance for paleoenvironmental applications

Martina Gocke and Yakov Kuzyakov

Department of Agroecosystem Research, BayCEER, University of Bayreuth, 95447 Bayreuth, Germany (martina.gocke@uni-bayreuth.de)

Interest in secondary (pedogenic) carbonates as an archive for paleoclimatic reconstructions in soils and sediments of arid and semiarid climates has increased during recent decades. Pedogenic carbonates are formed by precipitation of Ca^{2+} from the soil solution with dissolved CO_2 from soil air, originating mainly from root and rhizomicrobial respiration. Therefore, the isotopic signature ($\delta^{13}C$, $\delta^{18}O$, $\Delta^{14}C$) of pedogenic carbonates represents the conditions prevailing during their formation, and is widely used for reconstruction of paleovegetation, -temperature and -precipitation, as well as for estimation of the age of pedogenesis. However, for the interpretation of chronological and paleoenvironmental information from pedogenic carbonates, knowledge of the time frame of pedogenic carbonate formation is crucial. Formation rates and periods as well as the influence of climatic factors remain unknown.

The aim of this study was to reveal the influence of growing season temperature on pedogenic carbonate recrystallization. We hypothesized that temperature-dependent biotic processes like plant growth and root and rhizomicrobial respiration have stronger influence on soil $CaCO_3$ recrystallization than abiotic temperature-dependent solubility of CO_2 and $CaCO_3$.

In loess as a common soil parent material, initial $CaCO_3$ recrystallization rates were determined with the ^{14}C isotopic exchange approach by exposing loess several times to $^{14}CO_2$ released by root and rhizomicrobial respiration of plants labeled in $^{14}CO_2$ atmosphere at 10, 20 or 30 °C. ^{14}C recovered in recrystallized $CaCO_3$ was quantified to calculate amounts of secondary $CaCO_3$ and corresponding recrystallization rates, which were in the range of 10^{-4} – 10^{-6} day^{-1}. Recrystallization rates in rhizosphere were always at least up to 2 orders of magnitude higher compared to non-rhizosphere loess, demonstrating the importance of vegetation for pedogenic carbonate formation and recrystallization. Moreover, strongly increasing rates with increasing temperature showed the major role of biological activities for initial $CaCO_3$ recrystallization rates, especially rhizosphere processes like root and rhizomicrobial respiration and enhanced water uptake by roots, which are boosted by increasing temperature. The abiotic effect of lower solubility of CO_2 in water by increasing temperature was completely overcompensated by biotic processes. Based on initial recrystallization rates, periods necessary for complete recrystallization were estimated for different temperatures, presuming that $CaCO_3$ recrystallization in soil takes place mainly during the growing season. Taking into account the shortening effect of increasing temperature on the length of growing season, the contrast between low and high temperature was diminished, yielding recrystallization periods of 5740 years, 4330 years and 1060 years at 10, 20 and 30 °C, respectively. In summary, increasing $CaCO_3$ recrystallization rates with increasing temperature demonstrated the important role of vegetation for pedogenic $CaCO_3$ formation and the predominantly biotic effects of growing season temperature.

Considering the long periods of pedogenic carbonate formation lasting to millennia, we conclude that methodological resolution of paleoenvironmental studies based on isotope composition of pedogenic carbonates is limited not by instrumental precision, but by the time frame of pedogenic carbonate formation and hence cannot be better than thousands of years.