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Depth and rate of secondary carbonate accumulation in loess – ^{14}C pulse labeling column experiment

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Pedogenic (secondary) carbonates are formed under arid and semiarid climatic conditions by reprecipitation of Ca^{2+} in soil solution with CO_2 in soil air. In calcareous soil parent material, e.g. loess, this process leads to exchange of primary (lithogenic) carbon (C) with C from CO_2, derived mainly from root respiration and microbial decomposition of plant remains. The resulting relation between δ^{13}C values of soil CO_2 and of secondary carbonate is used for reconstruction of paleovegetation and paleoenvironmental conditions. For such studies, the time frame of pedogenic carbonate formation is crucial, but still unknown. Several environmental factors, e.g. vegetation, temperature, moisture, affect rate and depth of secondary carbonate accumulation.

Most soils of arid and semiarid regions contain a carbonate accumulation horizon (Bk, Ck, K), the depth of which is related to climatic conditions and properties of parent material. Based on C isotopic exchange during secondary carbonate formation, the aim of this study was to determine recrystallization rates and to localize the accumulation depth of secondary carbonate in an experiment with alternating moisture conditions.

Acrylglas columns of 1 m height were filled with loess and planted with maize for six months. Contrary to soil, this loess contains solely primary $CaCO_3$, has high $CaCO_3$ content (29%) and nearly no organic carbon. Thus, we simulated initial soil formation on loess. Maize plants were pulse labeled in $^{14}CO_2$ atmosphere at regular intervals of 3 weeks. Loess was wetted down to a maximum depth of 45 cm, and subsequent waterings were applied after the water level had decreased due to plant transpiration to less than 40% of WHC. After six months, plants were harvested and loess was cut into 5 cm slices. Amounts of secondary (recrystallized) $CaCO_3$ were determined in each of the segments based on the ^{14}C tracer assimilated by plants, then respired into rhizosphere and subsequently incorporated into newly formed secondary carbonate. After six months, 80% of recrystallized carbonate were leached from the uppermost 15 cm of the loess column, and 75% of total secondary carbonate were accumulated in a depth between 15 and 35 cm.

The experiment confirmed the hypotheses that

- water movement in loess leads to a clear accumulation zone of recrystallized carbonate (although total $CaCO_3$ content in loess was not changed after six months),
- the depth of carbonate accumulation is not related to depth of root penetration,
- the carbonate accumulation horizon correspond to the depth of wetting and drying.

Based on calculated recrystallization rates (in the range of 10^{-5} day^{-1}), leaching and accumulation of secondary carbonate, 1400 years are necessary for complete decalcification of the uppermost 15 cm of loess. Under the experimental conditions, this time interval represents the minimum age for formation of a calcic horizon.