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Evolution of isolated caves in porous limestone by mixing corrosion: A model approach.

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When water from the surface, e.g. from a lake flows through porous carbonate rocks down along some region with high hydraulic conductivity and encounters the water table of a phreatic aquifer both waters mix by diffusion along their boundary. In a carbonate aquifer, where both surface and phreatic waters are saturated with respect to calcite, mixing corrosion causes renewed dissolution capacity Δc_{eq} of the carbonate rock in the diffusional mixing zone extending from the boundary separating the phreatic water from the surface water encountering it. A numerical model is presented from which the initial change of porosity in such a diffusional mixing zone is obtained. The initial change of porosity can be calculated from the local distribution $m\,(x, y)$of the mixing ratio m and the second derivative of Δc_{eq} with respect to m. $m = V_{sur}/\,(V_{sur} + V_{phr})$, and the V's assign the corresponding volumes of surface and phreatic water. The second derivative has been calculated for three geochemical scenarios with differing CO_2-concentrations of surface and phreatic water by use of PHREEQC-2. The spatial distribution $m\,(x, y)$ is obtained by using MODFLOW and MT3DMS in a modeling domain with constant hydraulic conductivity for various flow velocities of the phreatic aquifer. From the results the time scale of cave evolution is estimated. Passages of dimensions of about one meter in width and several 10 cm in height, extending in length along the border line, where surface and phreatic water meet, can be created in time scales of 10 000 years. These caves are horizontal with blind ending passages and resemble closely to the isolated caves observed in Central West Florida. For more realistic modeling we have used a geostatistical local distribution of hydraulic conductivities in the modeling domain. For a correlation length of 1% of the length of modeling domain the spatial distribution extends deeper into the flow direction. When the correlation length is increased by a factor of 10 flow focusing distorts the diffusional mixing zone and enhances the creation of porosity.