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A fractal model of fissured and karstified aquifers applied to spring hydrographs

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The recession of spring hydrographs is frequently described using Maillet's equation, which predicts an exponential decay of discharge with time. However, the early stage of the hydrograph recession often deviates from the predicted behaviour. We propose a double-permeability approach to account for a non-exponential short-term recession. Conceptually, the spring catchment is composed of fissured porous blocks (matrix blocks) drained by a highly permeable network of prominent fractures or solution conduits (conduit system). We assume that the hydraulic conductivity of the conduit system is much higher than that of the matrix blocks. Thus, the spring discharge is obtained by superimposing the discharge from the individual matrix blocks. Assuming Darcian flow within the matrix blocks, scaling arguments reveal that the short-term recession follows a power law. The power-law exponent is found to be related to the spatial dimension of the conduit system; a dimension of one represents thin tubular conduits, a dimension of two planar fractures. The dimension of the conduit system may take non-integer values, as demonstrated by a geometric realisation for fracture systems with fractal dimensions between two and three. Applying the newly developed theory to recession curves from a karst spring (Gallusquelle, Germany) confirms a power-law decrease of discharge at short times. The fractal dimension of the conduit system supplying this spring is found to be 1.4, which may be interpreted as a fractal system of tubular conduits.