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Modelling and characterisation non-Fickian retention in fractured rock

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We study tracer retention in fractured rock based on a Lagrangian and a time-domain random walk formulations. Mass transfer is quantified by a retention time distribution that follows from a Lagrangian coupling between advective transport and mass exchange processes, applicable for advection-dominated transport. A unifying parametrisation is presented using two rates denoted by k1 and k2 where k1 corresponds to a forward rate and k2 to a backward (or return) rate. For the Fickian diffusion model, k1 and k2 are related to measurable retention properties of the fracture-matrix using the method of moment, whereas for the non-Fickian case dimensional analysis is used. The derived retention time distributions are exemplified both for interpreting tracer tests as well as for predictive modelling of expected tracer breakthrough curves. We show that non-Fickian effects can be notable when upscaling transport based on a non-Fickian interpretation of a tracer test where deviations from Fickianity are relatively small. The presented results improve our understanding of retention processes in crystalline rock and open new possibilities for interpreting tracer tests, as well as for use in predictive modelling of contaminant transport.