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Preferential flow paths in fractured rock detected by cross-borehole nano-iron tracer test

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Characterization of the preferential flow paths and their hydraulic properties is desirable for developing a hydrogeological conceptual model in fractured rock. However, the heterogeneity and anisotropy of the hydraulic property often make it difficult to understand groundwater flow paths through fractures. In this study, we adopted nanoscale zero-valent iron (nZVI) as a tracer to characterize fracture connectivity and hydraulic properties. A magnet array was placed in an observation well to attract arriving nZVI particles for identifying the location of incoming tracer. This novel approach was developed for the investigation of fracture flow at a hydrogeological research station in central Taiwan. A heat-pulse flowmeter test was performed to delineate the vertical distribution of permeable fractures in two boreholes, making it possible to design a field tracer test. The nZVI slurry was released in the sealed injection well. The arrival of the slurry in the observation well was evidenced by a breakthrough curve recorded by the fluid conductivity sensor as well as the nZVI particles attracted to the magnets. The iron nanoparticles attracted to the magnets provide the quantitative criteria for locating the position of tracer inlet in the observation well. The position of the magnet attracting the maximum weight of iron nanoparticles agrees well with the depth of a permeable fracture zone delineated by the flowmeter. Besides, a conventional saline tracer test was conducted in the field, producing a similar outcome as the nZVI tracer test. Our study results indicate that the nano-iron tracer test could be a promising method for the characterization of the preferential flow paths in fractured rock.