A Particle-Based Approach to Modelling Water Flow and Residence Times in a Small Catchment

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Introduction

Understanding water flow processes in the near-surface environment is crucial in determining movement of nutrients and pollutants. The majority of hydrological models used employ continuum-based expressions to derive mass flow linked with advective dispersive equations (ADEs) if transport is also considered. The appliability of these approaches to real soils which contain structural heterogeneities is questionable. Continuum-based models requires sub-grid equilibrium of potentials and fluxes, leading to impracticably fine grid-scales if the heterogeneities are to be represented, and the assumption of Brownian motion in ADEs is not representative of preferential flow features that allow solute movement at velocities much in excess of the wave celerities.

Multiple Interacting Pathways Model

The Multiple Interacting Pathways (MIPs) concept is an alternative approach to modelling transport and flow that directly acknowledges the presence of preferential flow pathways. Water in the slope or catchment is represented as a set of discrete particles, the movement of which is simulated through random particle tracking. Velocity distributions are applied to the particles, which attempt to characterise the range of pathways available to the water. These pathways are interacting as movement between them is simulated with exchange probabilities, which may also be used to simulate evapotranspiration or bedrock losses.

This concept provides unified simulation of transport and flow, allowing analysis of input/output/storage residence times and water origin, with the potential of adding chemistry to the particle interactions.

Application to Hydrometric and Isotopic Data

The MIPs model has previously been applied to simulating plot scale hydrometric and artificial tracer data at a site in Gårdsjön, Sweden with some success [1]. This modelling has been extended to simulate a catchment-scale step-change in isotopic input that occurred at the site on construction of a roof. Hypotheses are sought which provide consistent results across both spatial scales and temporal scales of transport. Having found a behavioural model, a fuller analysis is made of the input/output/storage residence time distributions suggested by the model.

[1] Davies (2011) Hydrological Processes **25**, 3602-3612.

Geochemical and isotopic insights into the origin of the 'Scourie' Dykes

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The 'Scourie' dykes are a NNW trending dyke swarm in the Lewisian gneiss terrain of Northwest Scotland. They represent important time markers in the evolution of the Lewisian as the majority were intruded between two regional high-grade metamorphic events – the Inverian (~2.5 Ga) and the Laxfordian (~1.7 Ga). Importantly, the area around Loch Assynt was variably affected by the Laxfordian event leaving some of the dykes un-metamorphosed with primary igneous textures and minerals. The dykes therefore are perfectly placed to distinguish between the metamorphic events and provide information on the Paleoproterozoic history of the Lewisian terrain. Numerous field, geochemical and geophysical studies have been conducted on the Scourie dykes over the past 30 years, despite this the age and origin of the dykes is still poorly known.

Field relationships and geochronology indicate that there are at least four separate Paleoproterozoic dyking events intruding the Lewisian crust spanning a period of more than 400 m.y. The majority of dated dykes using high precision U-Pb zircon/baddeleyite geochronology were emplaced between 2420 and 2380 Ma, which is the time period focus of this study. Whole rock and clinopyroxene oxygen isotopic analyses have shown that some of the dykes have low $\delta^{18}O$ signatures (~2‰) whereas other dykes have normal mantle values (~5.5‰). Geochemical studies of the dykes indicate that there maybe at least two mantle sources involved in dyke genesis that are variably enriched in trace elements.

Here we combine new Sm-Nd, Rb-Sr, $\delta^{18}O$, geochronological and trace element data on the dykes to suggest a new model for the origin of the 'Scourie' dykes. Preliminary results indicate that the initial pulse of dyke emplacement (~2420-2400 Ma) was characterized by normal mantle oxygen isotope signatures and mantle source enrichment. A second period of dyke emplacement occurred subsequently (~2400-2380 Ma) in which the dykes are less geochemically enriched and contain low $\delta^{18}O$ signatures possibly indicating the involvement of subducted oceanic crust. Using the new geochemical and geochronological classifications we define the 'Scourie dyke suite' senso stricto as those emplaced between ~2420 and 2380 Ma with a concentration of these dykes in geographic proximity to the town of Scourie.