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Using environmental tracers to develop a new conceptual groundwater model in southern Botswana

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Atmospheric noble gases, chlorofluorocarbons (CFCs) and sulfur hexafluoride (SF_6) are widely used as environmental tracers in aquatic systems. Here we present a multi-tracer study using dissolved atmospheric noble gases, CFCs (CFC-11 and CFC-12) and SF_6 in groundwater samples from Botswana, and use the results of the study to develop a conceptual model of the local aquifer system.

The aquifer investigated is located south of the town of Kanye in southern Botswana. Lithologically, the main aquifer consists of dolomite surrounded by different felsic and mafic magmatites and clastic sediments. The dolomite is strongly intersected by dolerite dykes.

Hydraulic borehole measurements and an existing groundwater model both suggest that the general groundwater flow is from west to east in a hydraulically coherent aquifer. However, the tracer data do not confirm this simplified model. At first glance the results for the different tracers seem to be mutually contradictory and not explicable by one consistent model. The CFCs and the ^{4}He- surpluses (crustal ^{4}He produced by the decay of U and Th) indicate decreasing groundwater ages from west to east. SF_6 was only found in the western groundwater samples. Tritium occurs predominantly in samples from the southern central area, and concentrations are generally very low. The concentrations of dissolved atmospheric noble gases measured in a groundwater sample can be used to determine its infiltration temperature. Most of the samples show infiltration temperatures of 20-24°C, agreeing with the climatic conditions that presently prevail in this region. Interestingly, three samples imply infiltration temperatures of about 17°C, indicating recharge under different climatic conditions.

A first interpretation of the analytical results suggests that there is most likely no single, uniform aquifer, but rather that the local groundwater system consists of several compartments that are more or less connected hydraulically. This might be due to the intersection of the dolomitic aquifer with the less permeable dolerite dykes. The ^{4}He- surpluses and the low infiltration temperatures of some samples suggest an inflow of old groundwater from an intrusive complex situated west of the dolomitic aquifer.

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Application of the multiscale finite element method to 3-D groundwater flow in heterogeneous porous media

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The multiscale finite element method(MFEM) is applied to 3-D groundwater flow problems in heterogeneous porous media with different change in coefficients in the paper. The method can efficiently capture the large scale behavior of the solution without resolving all the small scale features by constructing the multiscale finite element base functions that are adaptive to the local property of the differential operator, which offers significant savings in CPU time and computer memory. The characteristic difference between MFEM and the conventional finite element method (FEM) is attributed to base function. The base functions of MFEM can indicate the variation of coefficients in an element, but those of the conventional FEM can't do it. Two three dimensional groundwater flow problems in heterogeneous porous media are analyzed by the multiscale finite element method and the conventional finite element method, respectively. One is the three dimensional groundwater flow problem with gradual change in coefficients in the horizontal direction and in the vertical direction. Another is the three dimensional groundwater flow problem with the observation values of coefficients from the Borden test site. The solutions based on the MFEM are much more accurate than those based on the conventional FEM with the same mesh size for both problems. The accuracy of MFEM is significantly influenced by the boundary condition of the multiscale finite element base functions. The results using oscillatory boundary condition for base functions are much more accurate than those using traditional boundary condition. The applications demonstrate the advantages of the multiscale finite element method for numerical simulation of 3-D groundwater flow in heterogeneous porous media, i.e. significantly reducing computational efforts, and improving the accuracy of the solutions.