

# Radon concentration: A tool for assessing the fracture network at Guanyinyan study area, China

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## Abstract

The shallow subsurface in the Guanyinyan study area, China, is characterised by extensive fractures which are oriented NE, NW and EW. These fractures have lengths of about 200 to 300 m, and are spaced at about 1 to 7 m from each other. The bedrock is sandstone and mudstone overlain by a thin veneer of weathered rock and soil. These fractures are important from a hydrological perspective because the building of a dam is planned at this locality.

In an effort to quantify the density and openness of bedrock fractures in the Guanyinyan study area, RnA (daughter of Rn) concentrations within the soil cover were measured at 232 test sites. The expectation was that RnA concentrations within the soil would be anomalously high above and immediately adjacent to the fractures and that RnA concentrations could be directly correlated to the density and openness of the bedrock fractures.

On the basis of a statistical analysis of the acquired radiometric data and field observations, bedrock was classified into low openings (under 100 pulses of RnA), intermediate openings (100 to 200 pulses) and high openings (greater than 200 pulses). Low openings correspond to old fractures that have been filled, and intermediate and high openings to fractures that have been partly filled; this was confirmed in tunnels in the area.

This work has positive implications for the location of groundwater resources in fractured-rock aquifers such as in South Africa, where most aquifers are fractured rock.

## Introduction

A number of non-invasive geophysical techniques, such as resistivity and electromagnetics, have been developed to explore for fractured aquifers in areas where bedrock is overlain by soil of variable thickness. However, these methods have limitations. As both methods are sensitive to landscape and near-surface conductivity, and do not generally work well in humid, mountainous areas.

One non-invasive method that can be used effectively in humid, mountainous areas is the radon emanation method (Ku et al., 1977; Krishnawamis et al., 1982; Davison and Dickson, 1986; Ku et al., 1992; Ackerman, 1995; Ku et al., 1998; Brance and Xu, 2002). Levin (2000) applied this method as a tool in groundwater exploration in South Africa, where the passive Radon Gas Monitor (RGM) is used for locating permeable geological structures such as faults, shears and fractures. The limitation of the RGM method is that it is slow as it takes 2 or 3 weeks for obtaining final results.

Radon is a daughter product of uranium, thorium and radium. Uranium- and thorium-decay series disequilibria occur in groundwater as a result of water-rock interactions, and they provide site-specific, natural analog information for assessment of *in situ*, long-term migration of radionuclides in fracture systems.

The shallow subsurface in the Guanyinyan study area, China, is characterised by extensive fractures that are oriented NE, NW and EW. These fractures have lengths of about 200 to 300 m, and are spaced about 1 to 7 m from each other. The bedrock is sandstone and mudstone overlain by a thin scrap of rocks and soil. These fractures are important from a hydrological perspective because it

is planned to build a dam in this locality.

The technique discussed here has positive implications for borehole siting in South Africa where most aquifers are fractured rock, such as the Malmesbury Group and Table Mountain Group aquifers. Some of the fractures in these terrains have been multiply reactivated, and are characterised by deep groundwater flow. To locate optimal sites of water supply boreholes in fractured aquifers, it is necessary for the hydrogeologist to establish occurrence of the water-bearing open fractures. This method can be used to enhance success rates of borehole siting for groundwater supply and research.

## Radon transfer within a hydrological system

In a rock formation that is sufficiently old for the daughter nuclides to have grown into secular equilibrium, the activity of a parent nuclide is identical to that of its daughter nuclides. When the rock is in contact with groundwater such as in active structures, e.g. landslides, radioisotopes will redistribute themselves between the rock and water as a result of dissolution-precipitation, sorption-desorption, groundwater movement, and nuclear processes such as alpha recoil and radioactive decay, causing parent-daughter disequilibria (Ivanovich et al., 1992).

From the distribution of Rn, water-rock interactions and their effects on Rn transport in the aquifer or fracture were determined, including:

- *in situ* sorption-desorption rate constants and retardation factors of radionuclides;
- rates of precipitation and dissolution of minerals and their influence on radionuclide transport; and
- time of groundwater circulation in the aquifer. The latter also serves to delineate groundwater flow pathways at the site (Luo et al., 2000).

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