zones the crystalline rocks are considerably modified in such a way that the rocks acquire characteristics of an ideal sedimentary aquifer.

186-37 Poster Guarracino, Luis

A CONCEPTUAL MODEL FOR WATER CONTENT IN SELF-SIMILAR FRACTURED ROCKS

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Keywords: water content; fractured rocks; constitutive model

Simulation of groundwater flow in unsaturated fractured hard rocks has received considerable attention in the last two decades. One of the reasons for studying water flow in this particular type of porous medium is to investigate potential safe storage facilities for geological disposal of high-level nuclear wastes. Common numerical simulations of water flow in porous media rely on the continuum approach, where the solutions of the partial differential equations require expressions of both water content and hydraulic conductivity curves in terms of pressure head. In the hydrology literature several constitutive models have been proposed for sedimentary rocks but unfortunately these models are virtually nonexistent for fractured hard rocks. Thus, classical models developed for grained soils have been borrowed to represent constitutive relations for fractured rocks. The objective of this communication is to present a physical conceptual model for water retention in self-similar fractured rocks. Self-similarity is the major identifying feature of a fractal behavior and this property has been observed in fracture network structures of different geological formations. In this study the Sierpinski carpet, a classical fractal object, is used to describe the geometric pattern of a fracture network using appropriated cut-off values. The expression obtained for the water content is closed-form and all its parameters can be calculated from the density of the main fractures and the maximum and minimum values of the fracture aperture. The proposed water content model is then used to estimate the relative hydraulic conductivity of the fractured media based upon the well-known Bourdine model. Illustrative examples show that the shape of the water content relation is strongly dependent of both density and maximum fracture aperture while the relative hydraulic conductivity is mainly affected by the last parameter. Finally, it is important to remark that for small enough values of the fracture aperture the new constitutive model converges to the empirical Brooks-Corey model.

186-38 Poster Kim, Kue-Young

INTERPRETATION OF AQUIFER TESTS IN FRACTURED ROCK AQUIFER

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Keywords: aquifer test; fractured rock; GRF model; supply factor

Hydraulic analysis of fractured rock aquifer was performed using a simplified model based on aquifer tests. In order to analyze the hydraulic characteristics of aquifer at the study site, aquifer tests were carried out in fractured rock. Experiments were performed using three boreholes that were available at the site. Applying generalized radial flow (GRF) model to interpret hydraulic tests, the flow dimension was estimated to be nearly 1. Although there was no source bed identified by geological and geophysical investigations, a conceptual model is assumed to be one dimensional leaky confined aquifer based on the idea that around the major fractures that acts as a main aquifer, minor fractures are interconnected each other. These interconnected minor fractures function analogously as a source bed at a leaky confined aquifer. Analytical model is proposed considering the supply factor and recharge factor, and the dimensional and nondimensional boundary value problems are solved for hydraulic head using a Laplace transform technique. The results are obtained by the numerical inversion of the transformed solution. An evaluation of the solution with regard to parametric sensitivity is conducted and the results indicate that recharge factor doesn't affect significantly to the head as compared with supply factor. In addition, as a result of aquifer tests for the different pumping rates and pumping time, it shows that the velocity and the continuation of hydraulic pulse generated by the aquifer test is proportional to the magnitude and the period of hydraulic impact. The model proposed in this study simplified a complex fracture network and analyzed aquifer tests easily.

186-39 Poster Kim, Yongje

HYDROGEOLOGICAL CHARACTERIZATION IN FRACTURED AQUIFER SYSTEM

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Keywords: Fractured aquifer; hydrogeological characterization; connectivity of the fractures; flow path; conceptual groundwater flow model

The investigation of geological, geophysical, hydrogeological, and geochemical properties of fractured crystalline aquifer was carried out. Aquifer test was performed on five boreholes of 145 m depth to determine hydrologic anisotropy and major groundwater flow direction in the aquifer system of the study area. With an assumption of the aquifer's anisotropy and homogeneity, major and minor transmissivity were determined to be 12.21 m2/day and 10.47 m2/day respectively, and primary tensor direction for each borehole were also determined. The anisotropy ratio is 1.17, and the boreholes are hydraulically well connected.Borehole core logging, various geophysical well loggings, groundwater geochemical analysis, and tracer test were engaged in understanding groundwater flow characteristics. The chemical composition of groundwater in above and below the depth of 60-70 m was controlled by groundwaters in different origins. The high dissolved ions in groundwater below the depth is caused by the inflow of the groundwater in carbonate basement rocks, representing the upwelling of the deep grounwaters in the boreholes. High DO, F, and Cl as well as low pH in the groundwater sampled at the depth of 60-70 m indicated the connectivity of the fractures developed in the depth to the shallow depth of fractures, which was conformed by thermal tracer test. The

tracer test was performed with NaCl of EC 20,200 ㎲/cm and CTD diver to detect the tracer at the observation well. The depth of installation point of diver was determined by preliminary tracer test that includes thermal and conductivity tracer tests. The anticipated aquifer zone was around 15 m and 70 m depth from the surface. At the shallow depth the concentration range of tracer was 0.08-0.11, and the arrival time was 13-31 minutes. An unusual phenomenon appeared at the boreholes BH-4 and BH-5 that shows two breakthrough curves. It seems that the tracer has transported through two channels.Based on the results mentioned above, the data obtained from heat-pulse flowmeter test and tracer test were engaged in the conceptual groundwater flow model. As a result, in borehole BH-1, the permeable fractures were located at 7 points between 10 m and 71 m in depth and in BH-5, at 10 points between 15 m and 83 m. The flow path through fractures between BH-1 and BH-5 were determined at 15 m, 67 m, and 71 m in BH-1, and 15 m, 17 m, 22 m, 72 m, and 83 m in BH-5.

186-40 Poster Taioli, Fabio

GROUNDWATER FAVORABILITY MAP USING MULTICRITERIA DATA ANALYSIS ON CRYSTALLINE TERRAIN, SÃO PAULO STATE, BRAZIL

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Keywords: fractured-bedrock aquifer; remote sensing; GIS; geoprocessing multicriteria analysis; favorability map

This work presents the study of a fractured aquifer located in crystalline terrain, in the eastern portion of São Paulo State, Brazil. Remote sensing, airborne geophysical data, photogeology interpretation and geographical information system (GIS) techniques have been used. Lineaments, morphostructures, joint zones and slope maps were produced and geological, geomorphological, pedological and weathering mantle thickness maps have been digitalized. The first analysis consisted on cross tabulation between these maps and well yield data (specific capacity) using a GIS system.The results of these analyses had assisted to identify the groundwater prospective parameters, in a fractured-bedrock aquifer. So, with these analysis and bibliographic review, a hydrogeological model was defined. This model is the base for this favorability analysis whose principle is based on the knowledge-driven method.Experts (geologists experienced in bedrock-fractured aquifers) had attributed weights for each one of the factors and its respective classes, in the questionnaire form. The final values had been attributed by the authors (scale of 0 to 10), based on expert opinions and the analysis results.The identified prospective parameters, in the increasing order of importance are: lineaments (distance of lineaments and distance of its intersection), lithology (lithologic types and distance between geologic contacts), density joint zones, morphostructures, slope (0 to 30 degrees and greater that 30 degrees), geomorfology (morphology and dissection), soil type and weathering mantle thickness.The multicriteria analysis (index overlay method) was carried out to give a ground water favorability map, because the prospective parameters have different weights of importance and different classes inside of each parameter.The groundwater favorability map, with classes varying from 0 (low favorability) to 10 (high favorability) was tested (cross tabulation) with new well yield data and springs occurrence. The wells with the highest values of productivity, as well as all the springs occurrence are situated in the favorable and very favorable mapping areas. It shows good coherence between the prospective parameters and the well yield and the importance of GIS techniques to definition of target areas for detail study and wells location.

186-41 Poster Marinkovic, Goran

RADONIC MINERAL WATERS IN NATIONAL PARK KOPAONIK AND THEIR BALNEOTHERAPEUTIC IMPORTANCE

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Keywords: radonic mineral waters; springs; National park; Kopaonik Mt.

By hydrochemical researches in 2003. of groundwaters in National park Kopaonik, were discovered springs with concetrations of radon wich enable their categorization in radioactive mineral radonic waters. Formation of this radioactive waters is genetic in relation with fractured zones of granodiorite massif wich possess higher natural radioactivity according presence of mineral uranium. Mountain conditions plus mineral radonic waters, wich equally beneficialy reacting, at first place, on blood and nerv system, can do, with all natural beauties wich possess Kopaonik that this mountain become important balneotherapeutic center.

186-42 Poster Nuhovic, Sibela

HYPERALKALINE THERMOMINERAL WATER "SKAKAVCI" - DIVCIBARE (SERBIA) AND POSSIBILITIES OF ITS MULTIPURPOSE USAGE

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Keywords: hyperalkaline groundwater; fractured serpentinites; balneology

Groundwater with high pH values (>9.5) is known as hyperalkaline water. So far, knowledge about hyperalkaline waters in Serbia was mostly relied on area of western part of Zlatiobor ultramafites massif (Mokra Gora, area of Kremna, rivers Ribnica and Crni Rzav). This area is located in the western part of Serbia and characterized by great number of hyperalkaline water occurrences (about 20), where some of those have been used in balneological purpose, already.Hyperalkaline thermomineral water "Skakavci" is located south of Divcibare (village Skakavci) and relied on serpentinited harzburgites and destroyed zones within these rocks. Water is extracted by vertical drilled well, 800 m deep, with yield 0.5 l/s of free outflow. By well logging mainly fractured and destroyed serpentinites with occurrences of caverns were recorded until compact intervals are present occasionally.Water is characterized by very high value of pH=12, temperature of 25.7 oC measured at free outflow, and specific physical-chemical composition with main ions Ca, Na and OH. During the pumping test, 7 days long, with capacity of 8 l/s and with water temperature of 33 oC, Na-ion content remarkable increased in comparison with its content in free outflow regime. During the pumping test, white coloured deposits, probably MgCO3 appeared at the pump inlet.Hyperalkaline thermomineral water "Skakavci" - Divcibare is a new occurrence that will be object of future investigations. This water, concerning its temperature and specific chemical composition, on the basis of empiric gathered experiences, can have wide usage as "rare" curative mineral water with this capacity and quality. It should be emphasized that hyperalkaline Ca-OH water can have a great balneological value in external application (bathing) then skin diseases, kidneys diseases and gastritis medical treatment regarding its stable physical-chemical composition, bacteriological sterility and high pH value.

186-43 Poster Ranfagni, Luca

HYDROGEOLOGICAL AND GEOCHEMICAL STUDY OF A TUNNEL-IMPACTED AREA: THE CASE OF FIRENZUOLA TUNNEL IN THE MUGELLO REGION (NORTHERN APENNINES, CENTRAL ITALY)

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Keywords: Firenzuola tunnel; stable isotopes; water geochemistry; hydrogeology of tunnels; Northern Apennine

The Firenzuola tunnel (more than 15 km in lenght) is a part of the most important tunnelling work actually in progress in Italy: the Bologna-Florence new High Speed Railway. The tunnel crosses the Northern Apennine range, a large orogenic wedge mainly made up of turbidite complexes of Oligocene to Miocene age. The investigated area is environmentally valuable to the extent