Engineering Geology 163 (2013) 1–10

Contents lists available at ScienceDirect

Engineering Geology

journal homepage: www.elsevier.com/locate/enggeo

Combining structural and hydrogeological data: Conceptualization of a fracture system

Kálmán Benedek [a,*], Péter Molnár [b,1]

[a] Golder Associates Ltd., 500-4260 Still Creek Drive, Burnaby, British Columbia V5C 6C6 Canada
[b] Public Limited Company for Radioactive Waste Managemenet (PURAM), H-2040 Puskás Tivadar út 11., Budaörs, Hungary

ARTICLE INFO

Article history:
Received 3 November 2012
Received in revised form 28 April 2013
Accepted 26 May 2013
Available online 10 June 2013

Keywords:
Fracture
Hydrogeology
Scale dependence
Concept

ABSTRACT

In this paper a fracture system is studied based on hydrogeological observations and structural measurements at different scales from the Bátaapáti site, which has been chosen to store Hungary's low- and medium-level nuclear waste. It is argued that the combination of these two approaches may improve our understanding of the structure of the fracture system at different scales.

This paper presents the orientations, sizes, intensity, spatial locations and transmissivity of fractures at different scales in two hydraulic domains: 1) more transmissive zones, and 2) less transmissive blocks. Based on the evaluation of these properties, a conceptual model has been developed for the fracture system. The hydrostructural concept suggests that the complexity of fracture orientation and intensity increases with distance from more transmissive zones to less transmissive blocks but fracture size and transmissivity decrease. It also suggests that these parameters vary continuously between different hydraulic domains and that different parameters are strongly intercorrelated.

The complex interpretation of the fracture system studied can provide direct inputs for hydrogeological models, but can also provide conceptual information for the development of the geosphere module in safety calculations.

1. Introduction

The “safety case” (a determination of whether or not the proposed facility is able to safely perform its function in time and space) of a potential deep geologic repository for radioactive waste requires a sound understanding of both groundwater hydrogeology and potential radionuclide transport through the rock mass. Because the geosphere is the medium through which potential contaminants could leak to the biosphere, it is one of the most important components of the multi-barrier system. One of the preferred host rocks for constructing geological repositories is crystalline formation (IAEA, 2003).

The scientific literature discussing the characteristics of fractured, crystalline rocks place strong emphasis on the flow and transport properties of discontinuities, which are more permeable than the surrounding rock material — the matrix (Neuman, 2005). Fractures can be defined as planes along which stress has caused partial loss of cohesion in the rock (e.g., Singhal and Gupta, 1999) resulting in movement (slip) along the plane of discontinuity. In this paper, the term “fracture” is used for any discontinuity type including joints, fissures, cracks, and cleavage.

A fracture network is described by two main classes of parameters: geometrical properties and the combination of hydraulic and transport properties. Geometrical properties include fracture orientations, size (extent), intensity of fracturing, the location of fractures and relationship to specific geological or tectonic conditions. Hydraulic and transport properties include fracture transmissivity, storativity, and aperture. Given the difficulty in characterizing all fractures within a large volume of rock with only limited amounts of available data, it is usually necessary to build stochastic models based on statistical distributions of fracture geometric properties derived from sampling (Dershowitz et al., 1998). The stochastic fracture network models are often accompanied by only a few large-scale features (faults, deformation zones) that are important enough to be modeled deterministically. In the literature these deterministic faults are often referred to as “seismic scale features” since their geometric extents are usually determined from 2-D or 3-D seismic interpretation (Bourbiaux et al., 2005) or mapped on the surface.

The Hungarian repository program started at the beginning of the 1990s with a goal of finding a suitable disposal site for low- and intermediate-level radioactive waste. A detailed preliminary screening process selected a site in the vicinity of Bátaapáti in southern Hungary (Figure 1). The project started in 1997, and since then there has been continuous research and construction activity at the site. The target formation is composed of highly fractured intrusive igneous sequences of the Paleozoic Mórágy granite formation (Király and Koroknai, 2004). The initial aim of the exploration work was to evaluate the suitability of

* Corresponding author. Tel.: +1 604 296 7203.
E-mail addresses: kbenedek@golder.com (K. Benedek), molnar.peter@rhk.hu (P. Molnár).
[1] Tel.: +36 23 445996.

0013-7952/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.enggeo.2013.05.018

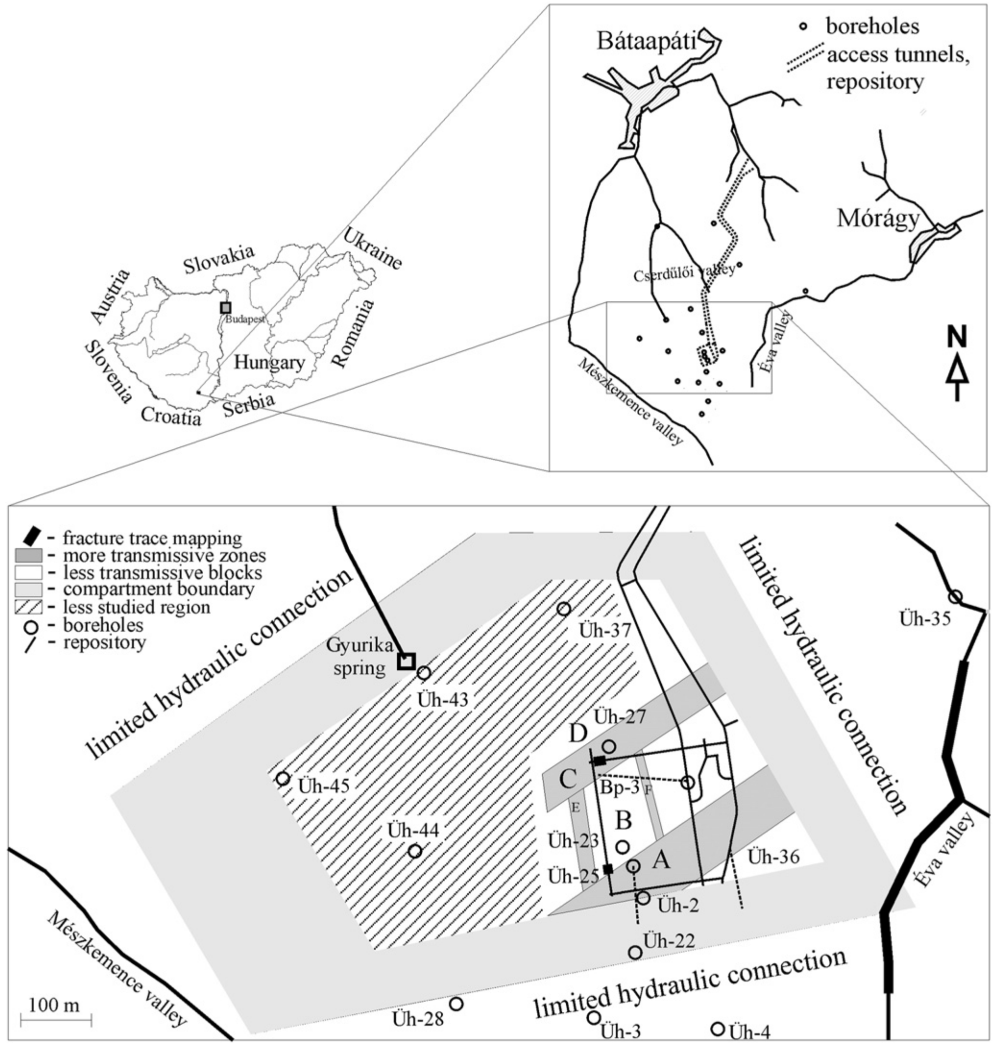

Fig. 1. Generalized map of the study area. A, C, E, F indicate the more transmissive zones (MTZ), and B and D are the less transmissive blocks (LTB). Note that in Fig. 1 only zones and blocks determined during field activities are displayed. In the western and northern extents of the site, the location of more transmissive zones is uncertain due to a lack of data.

the site, but later scientific research and design efforts have been conducted in parallel with the construction of underground infrastructure to ensure the long-term safety of the site. A wide spectrum of geoscientific exploration methods has been employed at the site over the last 15 years, including structural and petrographical interpretation of the granite, geophysical logging, geochemical sampling, and hydraulic testing.

This paper documents the characterization of the fracture system based on hydrogeological observations and structural measurements. The rationale behind this approach is that hydrogeological studies can provide dynamic information (connectivity, size, orientation) about flow in the fracture system in a 3-D rock volume while structural data (borehole images, outcrops, etc.) describe the static components (orientation, intensity, spatial model, etc.) of the fracture system. Applying the combination of these two approaches at the Bátaapáti site, two hydraulic domains were identified based on field observations: 1) more transmissive zones (MTZ), and 2) less transmissive blocks (LTB). Based on the data, a conceptual model is developed that may serve as the base of future predictive flow, transport and safety assessment calculations. The first half of the paper compiles all the available information about different fracture properties, while in the second part data are summarized in a comprehensive conceptualization of the fracture system. Finally, the practical implications of the concept are listed.

The analyses and conclusions presented in this article are based on data available before August 2011; data acquired during continuing construction efforts after this date were not considered. All the data used in this paper are available at the site's project portal (https://www.smartportal.hu/bataapati/index.php).

2. Site description

The Bátaapáti site is located in southern Hungary (Figure 1) within a geological environment composed mainly of intrusive igneous sequences of the Paleozoic Mórágy granite formation (Király, 2010).

Király and Koroknai (2004) described the composition of the Mórágy granite as porphyritic monzogranite, monzonite, and aplitic rock without sharp contact between the different lithologies. In addition, monzonite enclaves are frequently enclosed within the monzogranites found within the Mórágy Formation. More details on the petrology, petrogenesis, geochemistry, and metamorphic history of the intrusive complex can be found in Király and Koroknai (2004) and Király (2010).

The hydraulic interference tests carried out in several boreholes (Bradley et al., 2000) and the results of the hydrogeological monitoring system operating at the site indicate that the rock domain can be subdivided into several hydraulic compartments with very limited hydraulic communication (Benedek et al., 2009). At the boundary of different compartments, boreholes penetrated zones affected by intense tectonics such as sheared fault zones with intense mineral alteration and formation of clay minerals (Maros et al., 2010). Another observation was that within individual compartments, the hydraulic heads