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EXPLORATION OF A GRANITE ROCK FRACTURE SYSTEM USING A TV CAMERA

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ABSTRACT
This paper is dealing with a detection of ground water flow in a granite massif. The flow was studied between boreholes of a testing polygon situated in a granite quarry. So called cross-hole (C-H) tests were used to detect fracture based connection between the boreholes. The tests were proceeded in steady-state ground water flow conditions. There were TV cameras used to detect a uranine tracer. The cameras were equipped by an orange filter and well defined blue light. A geometrical model of the fracture system in the area of interest was proposed according to C-H tests data. A hydrogeological model was calibrated using the very same data. Results pointed out subhorizontal fracture connection between the boreholes. Main advantages of the TV camera usage are possibilities of accurate localization onto a structure, an immediate detection of tracer onset time and a continual data record.

KEYWORDS: granite fracture system, ground water flow, C-H test, tracer test, TV camera

INTRODUCTION

State of the art and tools of hydrogeology in a crystalline rock massifs environment are surely less developed in compare with the hydrogeology in a sedimentary basin porous permeability conditions. The issue of fractured rock massif aquifers became into a focus lately because of its specific characteristics. Low permeability of rock massif is an ideal characteristic when an underground gas container, a fuel bin or a long-time subsurface dump of radioactive waste is planned. A ground water flow in the crystalline rock massif environment characterizes several specific aspects. That is why it is more difficult to describe or even to simulate the water flow there in compare with the more frequently evaluated porous permeability condition water flow in the sedimentary basins. The crystalline rock environment is strongly heterogeneous and anisotropic. The fracture system within the rock massif, its character and density, dominates the water flow and transportation. The flow in the rock itself contributes into the global water transport through the massif much lesser.

The paper is dealing with an evaluation of in-situ field hydraulic and transport tests proceeded during the research project „ Methods and instruments of engineering barriers influence evaluation on remote interactions in the environment of an underground disposal site". The project was focused on testing and mathematical modelling of hydraulic and transport parameters in a fractured environment. The change of the parameters was studied after an engineered barrier had been applied in the part of the very same environment. There was proceeded an in-situ testing of natural fracture system within the rocks of a hydrogeological massif in the instrumented testing area. A test polygon was built up in a granite quarry close to Panské Dubenky village. Wide range of the geophysical, hydraulic and migration tests were performed. The aim of the performed tests was to obtain information allowing identification and hydrological evaluation of the fracture system.

LOCALITY

The test polygon was defined in a granite quarry close to Panské Dubenky village in the south-west part of the Jihlava district in the Vysočina region in the Czech Republic. From geographical point of view the area of interest belongs to Javořícské hory hills, part of the Českomoravská vrchovina highlands. The granite quarry occupies west slope of low-rise hill with a top climbing up to 694 meters above see level.

The quarry itself is approximately 650 meters above sea level. The quarry produce crushed and coarse aggregate. The test polygon can be found in a recently vacant part of the quarry. There were extracted approximately 10 meters of top wall granite at the polygon. Present-day geomorphology of the area is a result of the older structures uplift. These structures are of hercynian age and include deep magmatic bodies. The structures were uplifted during a formation of the Alpine-Carpathian orogeny. A rock massif fracturing and tectonic movements along NE-SW and NW-SE tectonic lines had accompanied the uplift and an allied arching.

The area of interest is formed by medium grained two-mica granite with a variant content of feldspar phenocrysts (Fig. 1). A WNW-ESE tectonic line borders the granite on the west. There are cover rocks e.g. biotite, sillimanite-biotite, flebite-nebulite migmatite with cordierite behind the line. There is another WNW-ESE tectonic line south of Panské Dubenky village. A west contact of the central massif rocks is shifted along this line about 500 meters to west. In so defined tectonic block the quarry is situated tightly close to the described WNW tectonic line (Fig. 2) (Vaněček et al., 2005). Twelve boreholes were made at location using core flush drilling. The depths of the boreholes were between 2.9 and 8.55 meters. The diameter of the boreholes was 76 millimetres. During the drilling water was used as irrigation. The groundwater level varies between 1.0 and 4.0 meters under the surface. Geodetic layout and elevation of the boreholes and other considerable points were measured at the place (Fig. 3). Results of hydraulic conductivity tests determined on borehole cores are discussed in (Sosna et al., 2007).

DESCRIPTION OF THE CAMERAS

The boreholes were examined using special TV cameras (Fig. 4). In the boreholes the cameras were used for scanning before and monitoring during tracer tests. The cameras were equipped with two optic filters and light sources to allow real-time tracer detection. It is possible to observe individual objects when the orange light and filter used. Combination of the blue light of defined wavelength 490 nm and the orange filter allows observation the fluorescence of a fluorescein solution only. Black and white TV signal is routed to TV card in a PC storing the images.

The borehole examinations provided information about standard of fractures, their dip and approximate opening. To measure the dip orientation of the individual fracture planes the compass was installed on the camera.

PRINCIPLE OF THE MEASUREMENT

Cross-hole tests were used to determine a course of the fracture system at the location. The tests were realized between selected boreholes to detect their possible fracture based connection. Every test covered a pair of boreholes. The tests were undertaken under steady-state groundwater flow regime with forced gradient conditions. Next figure displays the test scheme (Fig. 5). To insulate a single fracture there was a packer including a camera and a water-level measuring instrument placed into a grout hole. The pumping hole retained free. The cameras were placed on the each fracture level. Because of a relatively high rate of flow when gradient forced the original ground water was used as a medium. Thus a closed circuit emerged. Several measurements were proceeded during the tests. There were measured a ground water level within defined interval of a pumping hole and all a grout hole, a localization and onset time of a uranine pigment (Na-fluorescein) into a grout hole. C-H tests had started with pumping ground water out of the grout hole and in using the packer to the defined interval of the pumping hole simultaneously. Stabilization of the ground water level was tested by an installed pressure sensors. Limited amount of the uranine pigment was added into the injected water after the stabilization in both boreholes. First camera recorded a washout process of the pigment in the pumping hole. Three cameras monitored and recorded signal in the grout hole. The cameras registered the localization and the very moment of tracer onset into the grout hole. This approach allowed identifying any hydraulic connection between the tested couple of boreholes via particular fracture in the steady-state flow regime conditions.

RESULTS

In total there were analysed 24 C-H tests in selected borehole pairs. Following figure presents a typical operation test diagram (Fig. 6).

The plot displays a relative tracer concentration (0 to 255 in bites) to time dependence. First peak corresponds to inject of tracer. Next peaks are camera records in a grout hole. The plot clearly points out the tracer reached into the pumping hole via 94.39-relative-level fracture in two minutes. The signals from other cameras point to the vertical movement of the pigment in the borehole towards a pump placed below. Depth levels of fractures in boreholes are down counted relatively from the surface - the reference level 100 meters. Following picture (Fig. 7) shows schematic hydrogeologic cross section of the above mentioned C-H test. Groundwater flow during this test was 0.0472 L/s. Steady-state level difference between grout and pumping hole caused by the water flow was 0.12 meters. The transmissivity of the fracture (computed analytically by course of homogenous media) has a value 5.47×10^{-5} m^2/s.

Following scheme (Fig. 8) renders results of all performed C-H tests graphically. There are given levels where the tested pair communicates including a fracture location and penetration time. The times are incomparable because of differences in hydraulic gradients during separated tests.

CONCLUSIONS

The C-H test data were an input to a geometric model of fracture system at the locality (Polák et al., 2008). Hydrogeological model was calibrated by the very same data. The C-H test results pointed out subhorizontal fractures are the most common connection between boreholes. The subhorizontal fractures dip slightly towards the quarry wall. The conclusion corresponds well to a structure geology survey at the locality and to the informative fracture orientation and dip measurement during primary camera borehole exams. The use of TV cameras provided several advantages. The main advantages were an exact localization of measurement on the studied structure, an immediate detection of the tracer onset time and a continual data record.

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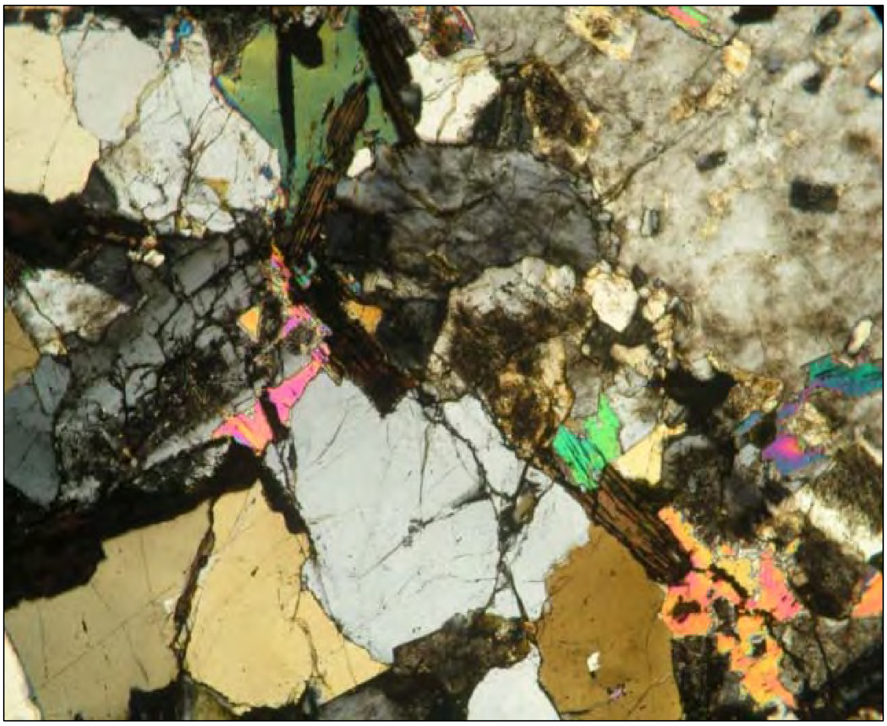

Fig. 1 Thin section of granite, XPL, magnified 40 times, adopted (Domečka and Sasínová, 2005).

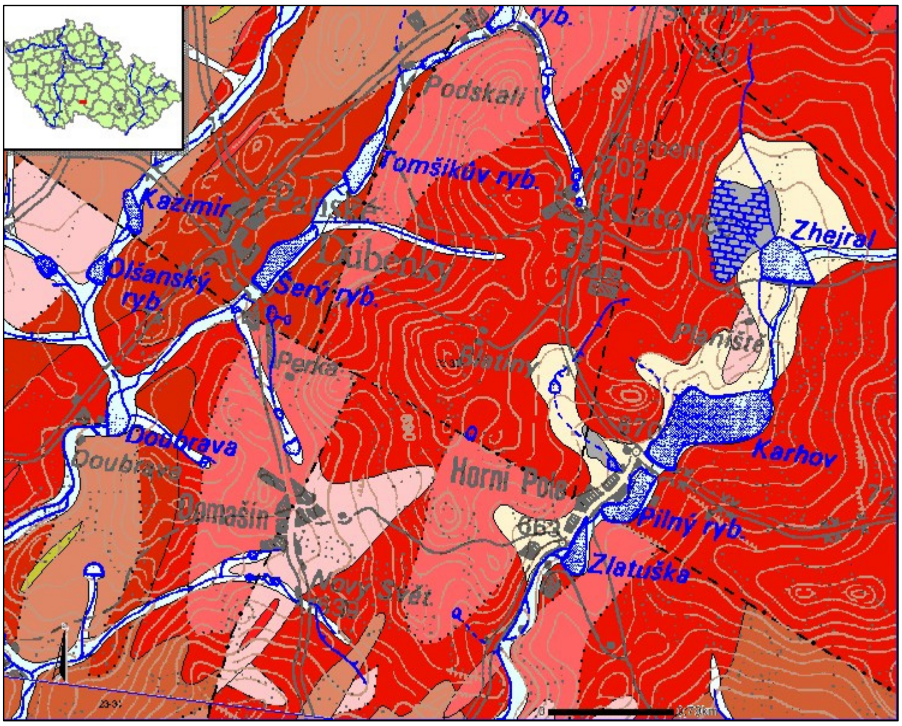

Fig. 2 Detailed geological map of the quarry vicinity.

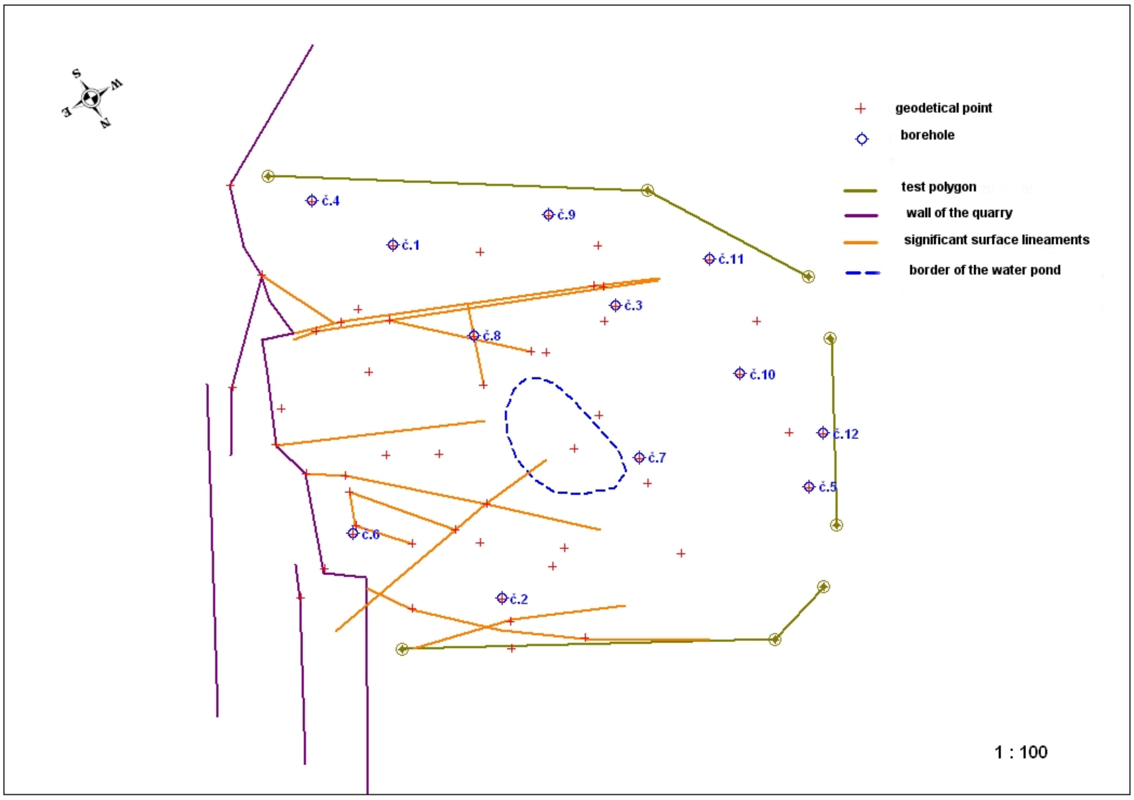

Fig. 3 Points and important lines in the area of the testing polygon, adopted (Polák et al., 2007).

Fig. 4 TV camera detail.

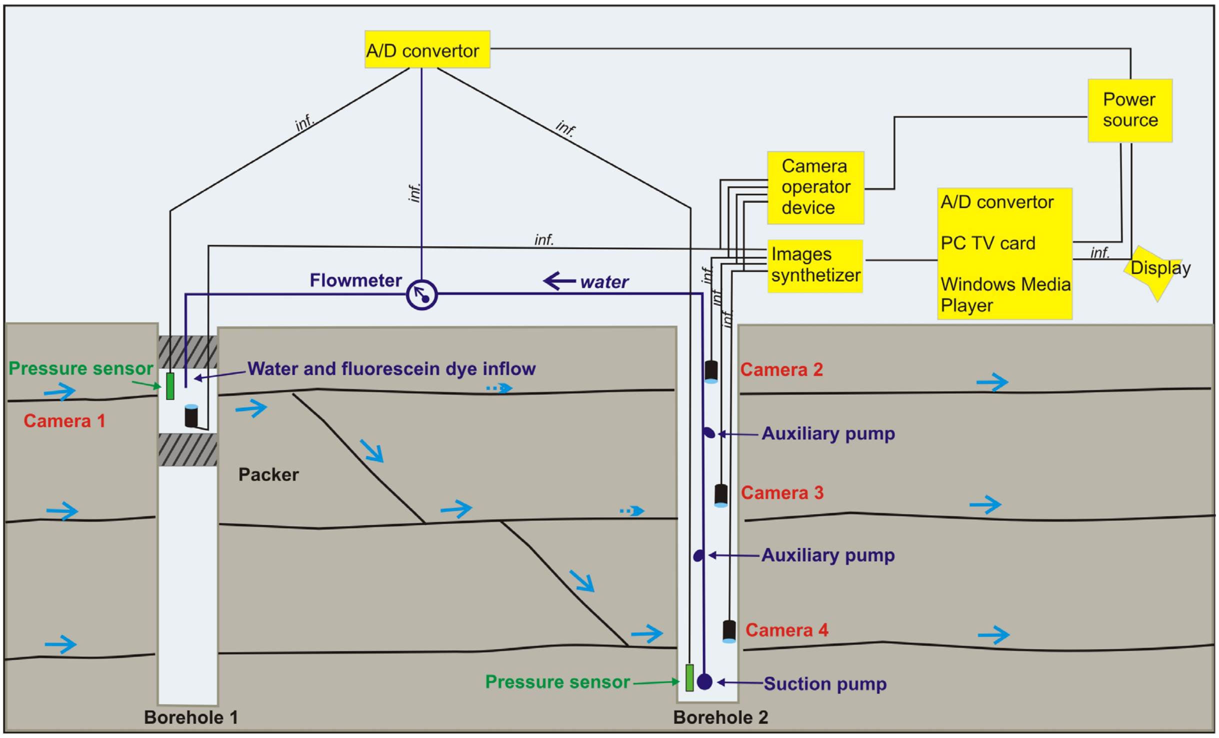

Fig. 5 C-H test scheme, adopted (Polák et al., 2007).

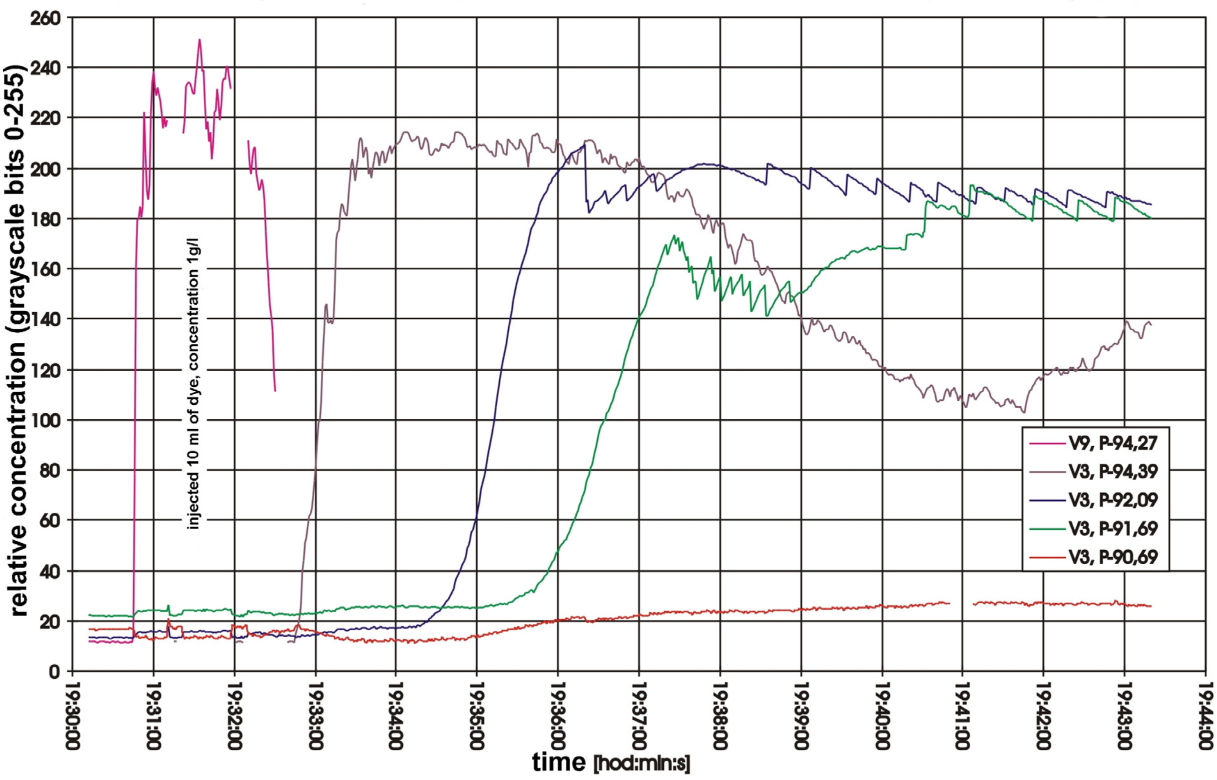

Fig. 6 C-H test plot, adopted (Nakládal, 2008).

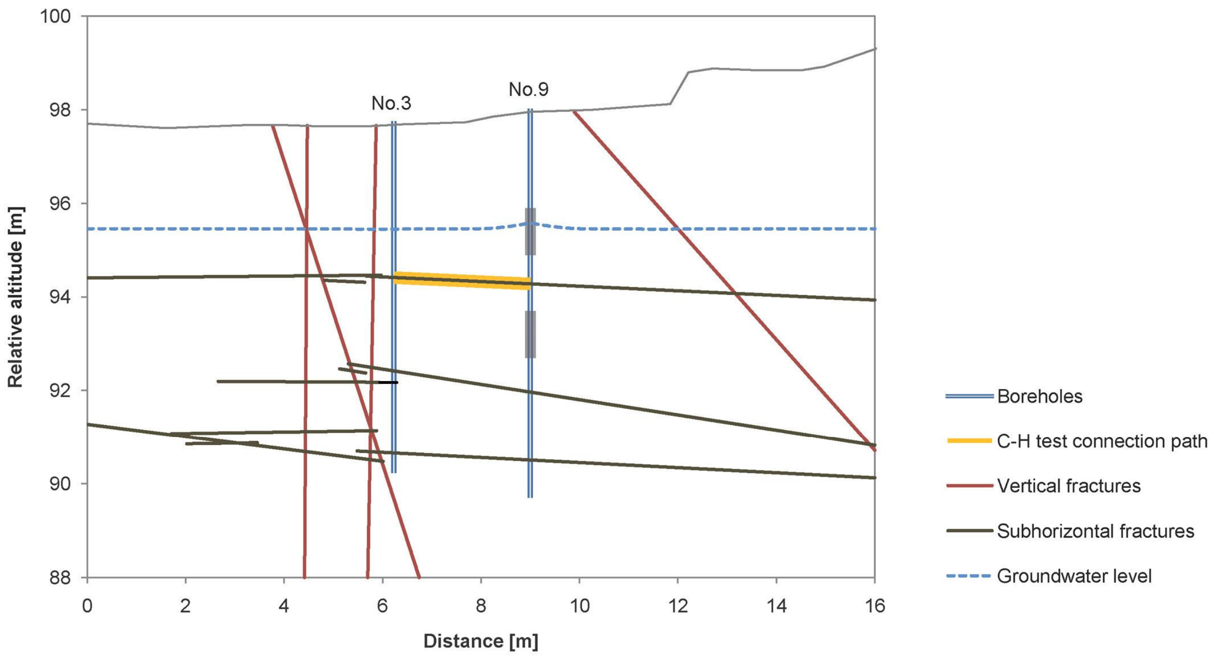

Fig. 7 Cross section of the C-H test.

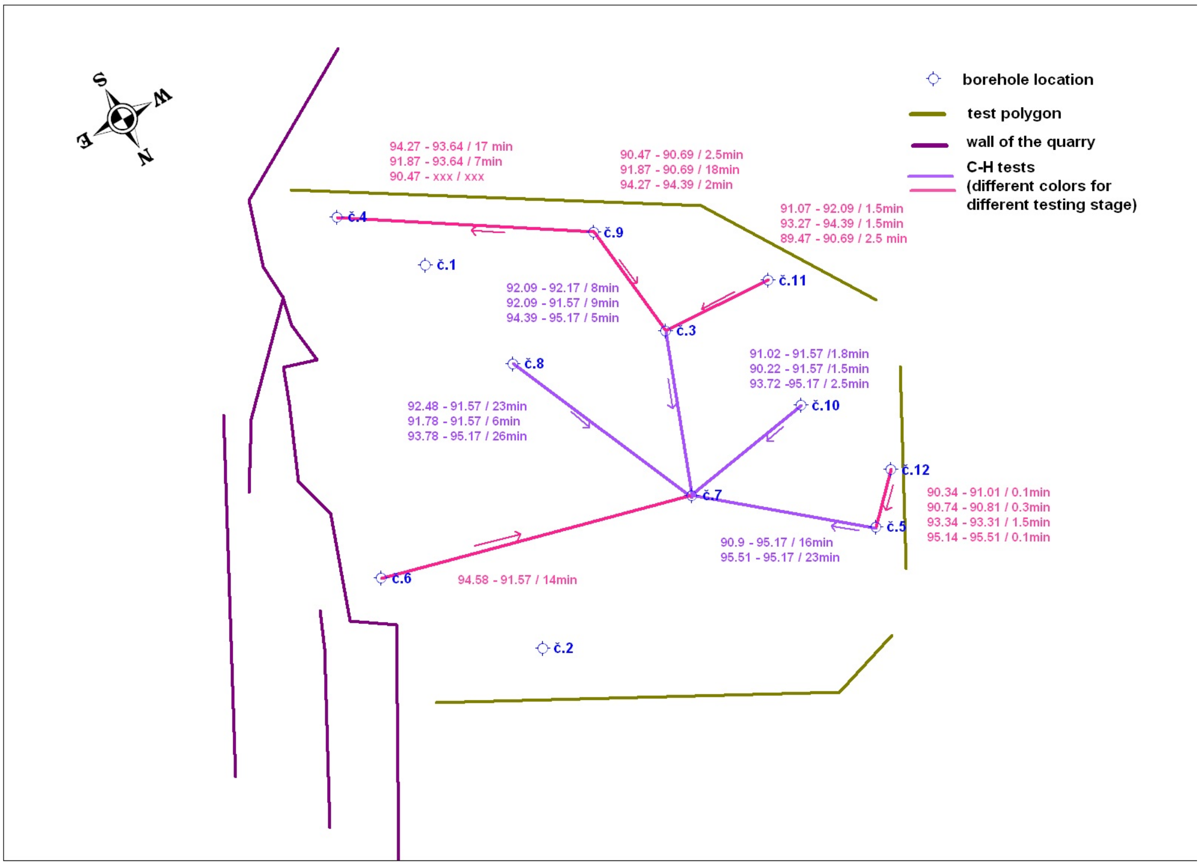

Fig. 8 Graphical representation of C-H tests, adopted (Polák et al., 2007).