Interval hydrodynamic tests at single boreholes in different rock environments

PETER MALÍK[1] & MARIANA SOPKOVÁ[2]

[1]Geological Survey of Slovak Republic, Mlynská dolina 1, 817 04 Bratislava, Slovak Republic;
E-mail: malik@gssr.sk
[2]Slovak Hydrometeorological Institute, Jeséniova 17, 833 15 Bratislava, Slovak Republic;
E-mail: Mariana.Sopkova@shmu.sk

Abstract: Results of 44 level hydrodynamic tests on 11 wells, drilled in hard rocks of Slovakia, are discussed in the paper. Position of more permeable intervals is compared with core logs and drill loggings. Quite contradictory results of this comparison are probably due to applied drilling technology, sealing the well surface during the borehole development.

Key words: interval hydrodynamic tests, boreholes, drilling, hydraulic conductivity, core logs, drill logging.

INTRODUCTION

Hydraulic properties of the rock environment with fissure or karst-fissure type of permeability, calculated from the results of hydrodynamic test performed on hydrogeological boreholes, are usually based on single borehole testing without checking hydraulic response on neighboring observation piezometers. This comes out from the drilling prices in hard rock media and the required depths of wells to be achieved in such rock environments. Pumping in different intervals during borehole drilling then represents the only possible source of information about hydraulic properties of different parts of hard rock environments, or about the vertical distribution of hydraulic conductivity values. One should note that packer technology is of seldom use in classical hydrogeological investigations for these purposes in the countries of Central and Eastern Europe at the time, because of its technological and financial requirements. The usual way to investigate vertical permeability distribution is to make interval hydrodynamic tests in different levels of the well deepening. These tests are generally run every 20 – 50 m of borehole drills. Interval pumping tests are of 4 – 72 hours of duration, sometimes including step-tests. Recovery test follows immediately, in the time span of 6 – 48 hours, and is believed to give more reliable data on rock mass properties because of not being disturbed by pumping rate variations.
In this paper, we tire to analyse material available from 44 hydrodynamic tests realised on 11 boreholes in Slovak Republic. Interpreted results of hydraulic conductivity and transmisivity values were then compared to the described by JETEL (1995). The results of the level hydrodynamic tests were also compared with core logs and geophysical drill loggings.

Scientific paper

APPLIED METHODS OF EVALUATION OF VERTICAL HYDRAULIC CONDUCTIVITY DISTRIBUTION

During the period of 1984 – 1998, 11 boreholes penetrating various rock environments were tested in various depths, on several locations of Slovakia. Their position is to be seen on Fig. 1. Results of pumping and recovery tests on single boreholes, yielding both transmisivity (**T**) and hydraulic conductivity (**k**) values for each tested interval were evaluated on unsteady groundwater flow pumping conditions, as well as by calculating of comparative approximate hydraulic indexes of permeability **Z**, transmisivity **Y** and logarithmic recalculation difference **d**, defined by JETEL (1995). **T** and **k** values were obtained by gradual simulation of the straight line defined by Cooper & Jacob semi-logarithmic simplification of the Theiss well equation (COOPER & JACOB, 1946 and JETEL, 1982). Hydraulic transmisivity values are plotted towards the borehole depths on Fig. 2. Records on the core logs and geophysical drill loggings in the boreholes (mainly resistivimetry, thermometry and calliper tests, but also of some more complex drill loggings as steady state and induced dilution resistivimetry) were compared with the hydrodynamic tests results. More detailed information about individual boreholes can be found in the Thesis of MARIANA SOPKOVÁ (2001).

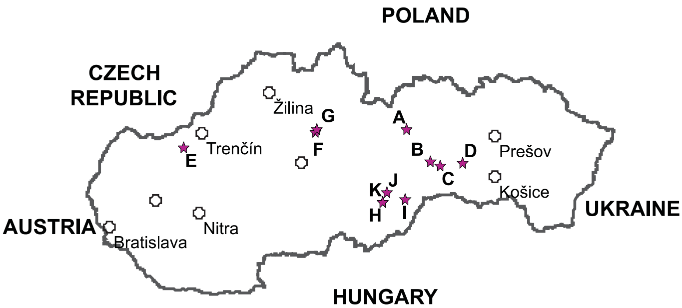

Figure 1. Location of evaluated boreholes on the territory of Slovakia

DISCUSSION

By comparison of the core recovery data, geophysical drill logging results and hydraulic properties of the rock media one can see, that the results in the case of boreholes drilled in the rock environment of crystalline and epimetamorpitic rocks, characterized by purely fissure type of permeability do not correlate. Intervals, characterized by pumping and recovery test as the most productive, are not the same as intervals signed by geophysical drill loggings as inputting groundwater, or the intervals with the poor core recovery. On the contrary, hydrogeological boreholes penetrating through the carbonate rocks (mostly of the Triassic age in Slovakia), showed relatively good relation of the hydraulic properties of the rock media calculated from pumping and recovery tests, and core recovery data and geophysical drill logging results, although in many times not between all of them.

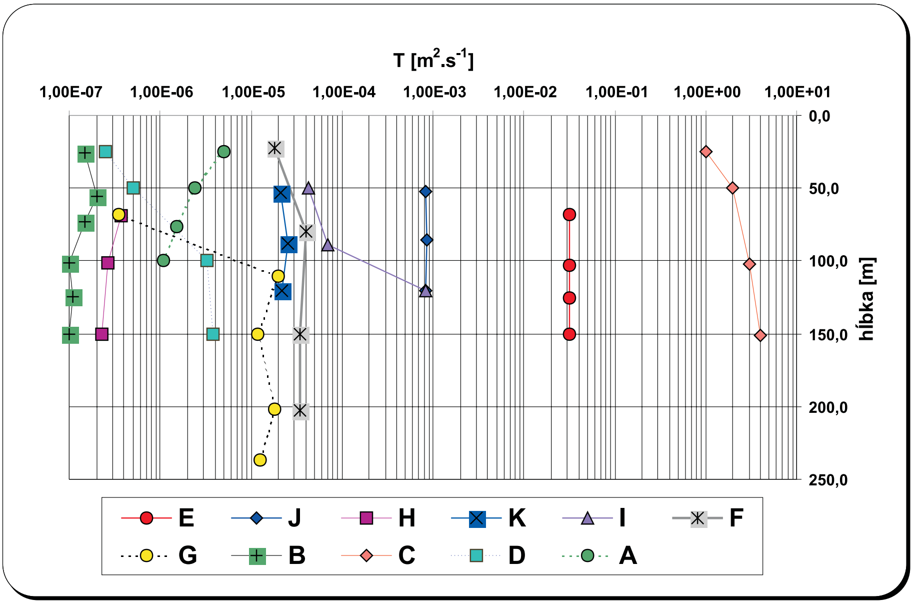

Figure 2. Dependence of transmisivity T [$m^2.s^{-1}$], derived from recovery tests, on borehole depths.

General decrease of hydraulic conductivity with depths corresponds with today's knowledge of vertical distribution of permeability in hard rock massifs – an exponential decrease of parameter **k** described by Jetel (1990). More interesting is the evidence of similar decrease of transmisivity values with depths (Fig. 2). One should take into account the way of testing individual intervals without any use of packer isolation, so in the majority of cases the new intervals were tested with all the previous ones, and their surpluses were subtracted from the bulk. It means that if the transmisivity value from hydrodynamic test is stagnant, the newly tested interval should be impermeable. But this is generally contradictory to the geophysical drill logging results, indicating at least some surpluses from greater depths.
The only explanation is the change of hydraulic properties of the borehole walls during the drilling process. Pumping and recovery tests were done immediately after reaching the particular depth. Geophysical drill loggings were usually measured after reaching the final borehole depth, before casing. In some cases, as casing was completed in two stages, also drill loggings were measured twice. During this time, with continuous drilling procedure, borehole walls could be affected. This possibility is maybe documented by **transmisivity decrease** with depths in the case of boreholes "A", "B" and "H" (Fig. 2), i.e., the less permeable rock environments. There is no other explanation for transmisivity decrease in the continuously deepened well, with the same + more intervals tested, than change of borehole walls properties during the period drilling.

Conclusions

Interval hydrodynamic tests on single boreholes in many times represent the only sources of information about the vertical distribution of permeability with hard rock masses. These tests are run during the stay of the drilling rig on the place, one should add the working (or staying) time of the machine on the place to the total price of the hydrodynamic test, and may represent 13 – 22 % of the total borehole price. Geophysical drill loggings in hydrogeological boreholes are sometimes used instead, to give the evidence of groundwater input levels, usually only with semi-quantitative estimates of inflows. Today, depending on the range of methods used, their price in similar conditions as previously mentioned, may represent 9 – 17 % of the total borehole price.

Comparing the permeability values from 44 hydrodynamic tests on 11 boreholes drilled in the rock environment with fissure and karst-fissure permeability types, with the geophysical drill loggings evidence of groundwater inflows and with core logs recoveries, the results were quite contradictory. Core recoveries, pumping and recovery tests, and drill loggings usually differently described the same interval. However, this difference was more evident in the case of boreholes drilled in purely fissured rock masses (granites, metamorphites, dolomites). Also, a change of hydraulic properties during the borehole deepening was detected by pumping and recovery tests in these rocks. On the contrary, karstified or slightly karstified rock environment gives more coherent results of both geophysical and interval hydrodynamic tests.

The documented transmisivity decrease with depths in the case of the less permeable rock environments is probably due to applied drilling technology (shot core drilling, but also in some cases the use of hard metal bit). This may cause sealing the well surface during the borehole drilling. Although only pure water was required and used as the flush media in all cases, small particles circulating within the water flush of the borehole can probably create a membrane, effectively isolating fissures with small aperture. In this case, the results of the interval hydrodynamic tests do not show the real rock mass properties, as these are masked behind the borehole walls permeability.

The population of the evaluated wells is too small to decide which of the mentioned methods gives the more representative results, and further investigation should bring more light to this problem.

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