PhD thesis report
"Structural and Petrophysical Characterisation of Granite Intended for Radioactive Waste Stocking"
by Martin Stanek

The manuscript presents the PhD thesis work done by Martin Stanek on a structural and petrophysical study of granitic formations in the Melechov massif (Czech Republic). The manuscript is divided into five chapters followed by four appendices, for a total of 210 pages. In the title it would have been better to write "storage" instead of "stocking".

The first chapter is an introduction in which the aim and the motivation for the project are described. Clearly the framework of the study is to characterize geological formations which could be potential targets for radioactive waste storage. Among other possibilities, granites are considered as interesting targets for nuclear waste repositories, but assessing the risks of such repositories requires thorough geological studies both at the field scale and at the lab scale. In his PhD thesis Martin Stanek has worked on both aspects. In this chapter, a description of the mechanisms of formation and segregation of granitic bodies is given, as well as some insight into fracture processes developping in granites. Finally a general overview of the Melechov Massif, the target of the present study, is provided along with a description of the different geological units and fracture systems found in the area of interest. It should be mentioned here that many references of previous works are given in this chapter, which shows that Martin Stanek has thoroughly studied the available publications and books on his field of research.

Chapter 2 presents a structural study of the Melechov Massif. Interestingly Martin Stanek has done both an exhaustive compilation of available structural data, and field work in order to fill the gaps in the compiled data set. Doing so he gathered an impressive amount of data on fracture, veins, joints and faults orientation, as well as on AMS (anisotropy of magnetic susceptibility). The statistical analysis of the complete data set leads to the construction of structural maps of the Massif from which a geodynamical interpretation on the development of magmatic fabrics was made possible. Three main structural domains were identified, each with different peak metamorphic conditions leading to distinct patterns in brittle and ductile structures. The analysis of fold axes and fracture orientation show consistent patterns, which are also consistent with magnetic fabrics inferred from AMS studies. Large variations in the intensity of magnetic susceptibility have also been detected when comparing the Lipnice and the Melechov granite. Although I am not a structural geologist, I can say that the structural study and compilation presented in this chapter by Martin Stanek is of good quality, and the interpretation of this large amount of data is sound.

Chapter 3 presents a petrophysical study on the effect of fracturation and alteration on the properties of the studied granite. This chapter is the longuest one of the manuscript, and represents therefore the core of the work done by Martin Stanek. Firstly the experimental setup used to measure thermal conductivity, elastic waves velocity and permeability is given, and the precision / limitation of each technique is discussed. For the thermal conductivity the experimental device allows one to get a continuous profile of the property across long core samples, so that the effect of heterogeneity and discontinuities can be investigated. Classical steady-state flow methods and ultrasonic techniques have been used for respectively permeability and P wave velocity measurements. For the latter, additional measurements on spherical rock samples were done to get some insight on the pressure dependence on elastic properties and on the elastic anisotropy. For the interpretation of the petrophysical measurements, the microstructural properties of the studied granite have been investigated using mercury injection tests, a well-known method in petrophysics. The sample collection is large, and includes both samples retrieved at different depths (< 105 m) in a borehole, and samples taken from several quarries in the studied area. Care was taken to cover a large variety of different situations : pristine rock, fractured and / or altered samples, etc... Each sample has been characterized also by mineralogical and structural analyses. All in all the amount of experimental data collected is quite impressive, and the challenge, which I think Martin Stanek has succeeded, was to make sense out of all the available data. The chapter ends with a discussion where the main features of each identified facies are recognized. For example specific signatures such as high permeability and porosity, low velocity, low thermal conductivity and associated anisotropy have been found for the weathered granite. Clear correlations were found between several

petrophysical parameters (e.g. permeability vs. porosity which is more or less expected, but also permeability vs. skeletal density which is less obvious), whereas in other cases no clear trends are observed. At the very end of the chapter a comparison with the structural data presented in Chapter 2 is intended. Whereas many interesting results are presented, there are some open questions which remain and have not be adressed : whereas AMS proved to be helpful for the structural study, one can wonder why AMS measurements where not measured and included in the discussion for the lab study. Also the general framework of the study must not be forgotten, and it was not explicitely said how this study can help in selecting a potential target for nuclear waste storage : what would be acceptable values for the permeability or the thermal conductivity for designing a repository in the studied area ?

Chapter 4 is an article published in Geophysical Journal International, which I actually reviewed some months ago. This article focuses on the elastic anisotropy and pore space geometry of shlieren granite from the same studied area. In this work experimental results on the pressure dependence of P wave velocities measured along 132 different directions on spherical samples are presented and are analyzed on the basis of microstructural evolution during pressurization. It is shown that the elastic anisotropy is controlled by the orientation of the shlieren which gives rise to a transverse isotropic symmetry with a minimum velocity perpendicular to the shlieren. The petrophysical fabric is compared to the microstructural one obtained from an analysis of grain boundaries, intergranular cracks and intragranular cracks orientations. This work has already been evaluated positively by the reviewers who found the research interesting enough to be published.

Chapter 5 is the conclusion where the work is summarized in only three pages which is rather short. Again as mentioned above the opportunity was missed to put this work into the perspective of what was announced in the introduction, namely the possibility of characterizing targets for nuclear waste repositories from such kind of analyses.

The work presented by Martin Stanek in his PhD thesis manuscript is of very good quality. Numerous results have been found from field and lab studies, and both help to understand the complex geometry of the granitic bodies in the area investigated. It is worth to mention that the large amount of data analyzed by the author resulted both from a thorough compilation of previous data and from extensive laboratory experiments to characterize the petrophysical properties of rock samples retrieved at depth from boreholes or on outcrops. The presentation of the results is very clear, the figures are well commented and all are useful. I regret that no photographs were included to show the outcrops where fracture analyses have been done, or where rock samples were retrieved. But this is a minor complaint in regard of the amount of work and the quality of the research presented in the manuscript.

For these reasons I have no doubt about the quality of the PhD work of Martin Stanek, therefore this work can be presented at the PhD defense in front of the committee in order for Martin Stanek to obtain the diploma of Doctor of the University of Strasbourg.

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