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Review of the Ph.D. thesis "Structural and petrophysical characterization of granite intended for radioactive waste stocking" by Martin Staněk

The Ph.D. thesis by Martin Staněk consists of five main chapters, a reference list, and four items in the Appendix. Below, I first comment separately on each chapter and then evaluate the thesis as a whole. My main queries to be explained or discussed during the defense are numbered and highlighted in italics.

Chapter I Introduction presents the main goals of the study and provides a brief overview of some general issues related to the formation of granite plutons. This section largely concentrates on the mechanisms of granitic magma transport through the Earth´s crust and then jumps straight to brittle fracturing. The overview is based on a good and balanced selection of modern literature and points out the current controversies of granite geology. However, what is definitely missing here is a similar overview of fabric formation in magmatic rocks and an introduction into the anisotropy of magnetic susceptibility (AMS).

[Q1] Why fabrics and AMS are not reviewed in the Introduction? These two topics are even more pertinent to this Ph.D. thesis than mechanisms of magma segregation or ascent.

Following this general overview, the thesis provides a brief description of geologic setting of the Melechov "massif". I find this quite a difficult task because most of the available information has not been normally published in peer-reviewed journals but is scattered in unpublished technical reports. Martin Staněk did a good job in compiling these reports. On the other hand, given that the thesis is largely focused on granites and not on their host rocks, information on the pluton itself could have been expanded. For instance, granites are only briefly mentioned (one paragraph on page 24) whereas host rock structures are described in a much greater detail.

[Q2] A more detailed account on mineral composition, whole-rock and isotope geochemistry, and compositional and textural differences between individual granite units would be desirable. Geochemical papers by Matějka and Janoušek (1998) and Harlov et al. (2008) should be cited in the thesis and discussed.

In addition, terminology is confusing in some places.

[Q3] The Melechov "massif" is in the same paragraph also referred to as "batholith" and is considered as part of the larger South Bohemian "Pluton". Most common usage of these terms is "plutons" for smaller and compositionally simpler intrusive bodies and "batholiths" for large, highly composite, and compositionally diverse bodies consiting of multiple component "plutons". Highly unusual terms are also "columnar batholith" and "subvertically prolate body". Note that "prolate" is used in structural geology to describe shapes of (strain, stress, AMS) ellipsoids.

Chapter II Structural characterisation of the massif is one of the two data sections in the thesis. As clearly stated in the beginning, this chapter is mostly reworking of structural data acquired by one of the advisors and his colleagues during their previous research. The chapter thus suffers from the lack of own field observations by the Ph.D. candidate (adding field photographs would really help the reader to appreciate how the structures look like) and raises some issues that could be further clarified.

[Q4] The AMS methodology is not described at all, there is no mention where the AMS data come from (laboratory, instrument, etc.) and how they were measured and processed (low field, high field, software used, etc.). More importantly, there is no table in the appendix listing all the AMS data, including station coordinates and measured AMS parameters for each station. There is also a discrepancy between 34 stations shown in the AMS maps and 60 stations mentioned in the text.

[Q5] The AMS directional data are presented only in maps as the mean magnetic foliations and lineations. This way precludes rigorous analysis of the data, especially the degree of clustering of the principal susceptibility axes on each station, i.e., how well the mean axes are defined. At least in the appendix, there should be stereonets provided showing the principal susceptibilities, mean susceptibilities, and confidence ellipses for each station. I also wonder why there are no summary stereograms of the principal susceptibility axes included as separate figures.

[Q6] Typical for comparable two-mica granites, the bulk mean susceptibilities reported in the thesis are low, on the order of 10^{-5} to 10^{-4} suggesting paramagnetic minerals (micas) as the main carriers of the AMS. I find the explanation of these subtle differences in K_{mean} speculative. The higher susceptibilities in the eastern part of the pluton, and in particular in the Lipnice granite, are interpreted to reflect higher degree of in situ partial melting as compared to neighboring migmatites or higher total strain recorded by the melt or as representing an assimilated stoped block. In contrast, as shown by Hrouda and Kahan (1991), variations in modal concentration of biotite and muscovite by a few percent may account for changes in the K_{mean} by an order of magnitude (for 1–10 % of biotite the K_{mean} is between 10^{-5} and 10^{-4}). The Ph.D. candidate thus should make a convincing case that the differences in the K_{mean} reflect the proposed processes (extensive in situ melting, strain,

block assimilation) and not only magnetic mineralogy.

[Q7] I find similarly uncertain the interpretation that the oblate shapes of the AMS ellipsoids in the Lipnice and Kouty granites "suggest affinity to the planar metasedimentary fabric". Single mica crystals have an oblate magnetocrystalline (intrinsic) anisotropy. Thus the granites where micas are the main AMS carriers will tend to exhibit oblate fabrics just due to their magnetic mineralogy.

[Q8] "Granitisation" is mentioned in several places in the text, especially in relation with the older granites, without a more detailed definition of this process. How exactly these granites were formed? In situ metasomatism (=granitisation)?

[Q9] Schlieren are frequently mentioned in the text but are nowhere defined nor described in detail (mineral composition, grading, younging, geometry, relations to fabric). In consequence, the interpretations regarding folded schlieren need further explanation. Are they relics of folds inherited from the host migmatite? Or did they form in magma by some process of mica accumulation (which one?) and were then folded into magmatic folds? Which arguments support either interpretation?

[Q10] There are two early sets of joints defined in the pluton. Set 1 (WNW–ESE) is interpreted as reflecting regional tectonic stress during pluton cooling (joints are continous across pluton margins to the host rock) whereas Set 2 (NNE–SSW) is relatively younger, confined to the pluton, and interpreted as being less controlled by tectonic stress (=dominated by thermal cracking). These inferences need further explanation. First, discussion of these results against those presented by Bankwitz et al. (2004) would be interesting. These authors suggested that the NNE–SSW joints were the earliest to form in the Moldanubian batholith (or whatever you call it), just after solidification of the granites. Second, what caused that joints formed by tectonic stress were replaced by joints formed by thermal cracking? I would expect exactly the opposite: a switch from early cooling-driven jointing due to higher thermal gradients between pluton and host rock to later tectonic jointing as the temperature gradient diminishes and becomes increasingly overridden by tectonic stress.

[Q11] Based on map trajectories of Set 1 and Set 2 fractures, it is inferred that the outer portions of the pluton underwent significant dextral and sinistral shearing associated with strike-slip movements along major faults. This implies that large portions of the granite were pervasively reactivated in solid state, magnetic fabric has been rotated by these two shearing events, and also the early fractures of Set 1 must have been rotated by Set 2. Maps do not show this (in addition to the fact that the faults are nowhere documented in the thesis). For example, magnetic lineations in the western portion of the Kouty granite seem unaffected by the kink in Set 1 fractures. Similarly, lineations in the southern half of the Lipnice granite are not deflected by the kink of Set 2 fractures.

Chapter III represents the mainstay of the thesis and contains abundant laboratory measurements of various petrophysical properties (thermal conductivity, P-vawe propagation velocity, permeability, and porosity) of granites showing various degree of alteration. This section is very well organized. Each method is described in detail including the underlying theory, experimental setup, and proper descriptions of samples and results. Relations between the measured properties are then very clearly portrayed in a set of diagrams. The chapter is concluded by an interesting discussion of relations among fracture orientation, degree of alteration, porosity, and fracture connectivity. I found no significant problems in this section.

Chapter IV is a paper published in Geophysical Journal International. This chapter already passed trough the peer-review process and thus requires no further review. From a formal point of view, it should be checked if inclusion of a published paper in the thesis complies with the Charles University regulations and is not in conflict with the copyrights owned by the publisher (note that the thesis will be displayed on the web).

Chapter V Conclusions briefly summarizes the previous results and main points of each chapter.

Formal quality of the thesis

The whole thesis is very well organized and clearly written. I found only a few minor typographic errors. All illustrations are of high quality.

Final statement

Despite some issues outlined above that could be a matter of debate, I am pleased to conclude that the Ph.D. thesis by Martin Staněk is an excellent piece of work which would certainly merit the award of a doctoral degree at the Charles University in Prague. I strongly encourage the committee to vote positively on Mr. Staněk's behalf.

Jiří Žák

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