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Review PhD thesis, Lukas Ackerman

The PhD thesis submitted by Lukas Ackerman is comprised of 5 parts. In Chapter 1 a brief review of the composition of upper mantle rock occurrences in the Bohemian Massif is given. This chapter serves as an introduction into the thesis subjects. Chapter 2 is a paper on the major element and lithophile trace element geochemistry (including Sr and Nd isotopic data) of peridotite xenoliths from Kozakov volcano. Results from previous geophysical work are combined with the geochemical data to develop a model for the composition and structure of the lithospheric mantle underneath this area. This paper was published in 2007 in *Lithos*, a high-impact international journal on petrology and geochemistry. Chapter 3 deals with abundances of some highly siderophile elements (elements with very high metal-silicate distribution coefficients that occur at ppb to sub-ppb level in the Earth's mantle) and Os isotopic compositions ($^{187}\text{Os}/^{188}\text{Os}$ is variable due to contributions of ^{187}Os from the decay of radioactive ^{187}Re) in some of the same peridotite xenoliths studied in Chapter 2. The focus of this chapter is on understanding the low and variable abundances of the HSE in these peridotites coupled with "normal" mantle-like values for $^{187}\text{Os}/^{188}\text{Os}$. Various processes are discussed that might explain the unusual HSE abundances. Chapter 3 has been submitted as a manuscript to the highly regarded international geochemistry journal *Geochimica Cosmochimica Acta*. In Chapter 4, the geochemistry of Mg and Fe rich peridotites and pyroxenites from a peridotite body from the Gföhl unit is discussed (major and lithophile trace elements, Sr and Nd isotopes). The Fe rich dunite-wehrlite assemblage is interpreted to have formed from melts that reacted with "normal" mantle peridotites. This chapter has been submitted to *Chemical Geology*. The overarching theme of the thesis is to understand, by means of various geochemical and petrological data, what kind of processes have modified the composition of mantle peridotites from the Bohemian Massif. Chapter 5 serves to synthesize the results from the preceding chapters. Some open questions and suggestions for further study are provided here.

Overall, the thesis and the three papers that represent its core are a fine piece of work, and I commend Lukas for his hard work and diligence in pursuing his research. The data have been (in case of Chapter 2) or will be published in excellent international journals, indicative of the high quality of this work. Thus, I enthusiastically support acceptance of this work as PhD thesis.

Because science is always about weighing incomplete data and evidence, and there are always different opinions and viewpoints, I would like to add a few specific comments on some of the chapters. These comments should be passed on to Lukas (in fact, I have no objection against letting him know the full content of the review). I believe he, as any fresh PhD, will benefit in his development as a scientist by critical assessment of weak points in the interpretative sections.

Chapter 2:

1. The assignment of pressures (= depth estimates) to the geothermometry results for the peridotite is strongly dependent on the validity of the heat flow/geotherm model from the Christensen et al. paper. Transferring this model to the peridotites and their textures assumes that these indeed reflect the gradient 5 Ma ago. This assumption is very difficult to test and may be right or may be wrong. Some of the textures and mineral compositions could reflect local (!) frozen-in thermal perturbations, related to the transport of magma (there is chemical evidence for the latter, right?). A possible hint for such problems comes from the fact that some fertile samples that are supposed to come from greater depth contain spinel, but no garnet. The depth of the spinel-garnet peridotite transition strongly depends on the Cr number of the rock. For instance, ORKZS6 is very fertile and has a low Cr#. At 60 km, one would expect at least a little garnet in this sample. Another fertile sample is 94KZSM7, also with a low Cr#. This one is supposed to come from 70 km depth, but contains no garnet. It might be worth to check again some of the experimental work (such as Nickel, Neues Jb. Min. 1986 or more recent work by G. Brey).

In the following chapters, the depth-temperature estimates of the samples are taken as a given, even though, one might consider those as shaky.

2. The spinel-px symplectites in the protogranular samples are interpreted as garnet breakdown textures (this is also a common interpretation in the literature for similar textures found elsewhere). What argues against an interpretation as breakdown products of Al rich high-T pyroxenes that precipitated from percolating melt in the spinel peridotite facies?

I have never seen such textures containing any relic garnet, even though kinetics in dry samples is usually slow. On the other hand real garnet peridotites (xenolith or massif) often contain relic garnet and the breakdown products seem to look differently.

An interpretation not involving garnet will do away with the awkward situation that requires explaining a garnet peridotite layer sandwiched between two spinel peridotite layers.

3. It is difficult to see any depth-dependent systematics in Fig 7 or 8. The slopes of the patterns vary, as do positions of the minimums, however, this might be accomplished even by lateral chromatographic effects over short distances (see work by the Bodinier group). In contrast to what is claimed in subsequent chapters, Figs. 9 and 10 show no systematic differences between deep and shallow samples of the same textural type. For some ratios there is indeed a subtle trend for the

protogranular samples. Thus, there is no simple relation of chemistry (such as LREE enrichment) with temperature or presumed depth.

4. The preferred model for the xenoliths seems to be that they are residues of partial melting with some overprint of abundances of more incompatible trace elements such as the LREE by “cryptic” metasomatism. The correlations in Fig. 6 are cited in support for this model. Linear correlations of relatively incompatible elements such as Ti and Na with Mg are inconsistent with fractional melting models, as discussed by numerous authors in the literature (Don Elthon was the first to observe this in a paper in JGR). The current consensus seems to be that while the harzburgites in such correlations may be melting residues, many fertile peridotites have been affected by some form of cpx addition, i. e. the correlations would be mixing lines. This form of modal metasomatism may be difficult to identify texturally, if the peridotites have undergone recrystallization. In this context, I recommend reading the recent paper by Le Roux et al. (2007, EPSL), where textural evidence for these processes are shown. The HSE abundance data in Chapter 3 is used to argue for substantial open system behaviour and melt percolation. It is very difficult to conceive that the modal composition and hence, major elements were not affected.

Chapter 3:

1. Following the reasoning given above, it is clear that the correlations of incompatible HSE (Re, Pd) with elements such as Al observed for other peridotites (p. 62) also should reflect mixing between melts and depleted residues.

2. The low abundances of Os, Ir and Ru in most of the peridotites and the large variability of Pt and Pd are indeed most plausibly explained by some form of melt percolation process, similar to those advocated in the literature. From studies of spatially controlled samples from peridotite massifs (Becker et al. 2001, EPSL; Büchl et al. 2002, EPSL), it appears that such compositions are associated with high melt/rock ratios, which are restricted to zones of highly focused magma flow. From this perspective, one might ask, how representative these xenoliths are for the composition of the lithospheric mantle underneath the studied volcanic center. It is noteworthy that the bimodal distribution of Ir data from peridotite xenoliths in general may suggest a biased sampling of lithospheric mantle by xenoliths.

3. Some of the variability in Re/Os in the peridotites discussed on p. 65 may not simply reflect the different partition behaviour of Re and Os, but almost certainly may reflect variable Re contents in the melts. The discussion in discussion also suggests that there are systematic differences between the different layers in HSE concentrations and ratios. I cannot see any systematic differences in Figs. 6 and 7.

4. On p. 65/66 it is concluded that radiogenic Os was not added to the peridotites. If the melts had subchondritic to chondritic $^{187}\text{Os}/^{188}\text{Os}$, it would be difficult to detect how much Os has been added from the melt and how much has remained from the previous history of the rocks.

5. Given the evidence for extensive modification of the HSE abundances of the peridotites, and absence of any correlation of Os isotopes with Al or Re/Os, it is difficult to assign any geological significance to the apparent Re-Os model ages. The scatter of age values supports such a view. We have found similar scatter in Re-Os model ages for metasomatized garnet peridotites from the Bohemian massif (Becker et al. 2001, EPSL).

(Prof. Harry Becker)