REPORT

on the Doctoral thesis of Helena Zlebcikova called
„Anisotropic tomography of the European upper mantle“

The above mentioned manuscript is very well organized. It is divided in 7 chapters and 2 supplements covering the development of a new code for anisotropic teleseismic tomography, the thorough test of the new method with
synthetic data with a particular focus on the aspects of damping and a first application of the new code to the real dataset of the LAPNET project.
The manuscript is organized as a kind of a composite thesis, i.e. the core of the thesis consists of two chapter on the theoretical aspect of the work (chapters 3 and 4) and two high-class peer-reviewed research papers (chapters 5 and 6) with additional chapters outlining the scientific ratio for this particular work, the theory of seismic anisotropy with special attention to seismic tomography and a short summary at the end.

While Chapter One is giving the scientific ratio for the development of a new inversion code which will solve not only for the isotropic velocity perturbations but also for the inherent upper mantle anisotropy, is Chapter Two giving the derivation of the equations used in the new code "AniTomo" with a special focus on the chosen anisotropic symmetry. This choice of symmetry is based on the experience of seismologists studying the observation of seismic anisotropy in the upper mantle beneath continents and is a necessary ingredient to limit the number of unknowns to a manageable level. Even with the vast amount of new seismic data is the solution with a very general anisotropy approach not feasible since it will result in a too large number of parameters which are essentially not manageable (no stable solution when inverted for). Chapter Three is dedicated to the forward modelling of P-wave traveltimes for a given arbitrarily heterogeneous anisotropic model. The forward calculation of traveltimes is an option, which helps to visualize the anisotropic pattern expected for P-wave residuals for an a-priori given type of anisotropy and which allows to calculate so-called synthetic P spheres which are then compared to observations. One might see this as a kind of pedagogic feature to explore the range of anisotropy systems one could expect. Chapter Four focuses on a first testing of the functionality and the strengths and weaknesses of the new code for a rather simple model which helps to understand some of the limitations of the approach as such. Chapter Four might be seen as the prequel to Chapter Five. Chapter Five deals with a subsequent series of synthetic tests and mimics tomographic inversions with a realistic parametrization of an upper mantle volume. While Chapter Five thoroughly discusses the chosen parametrization in terms of resolution one can expect and very nicely shows the separation of the isotropic and anisotropic components of the model parameters, it is however limited to a rather unrealistic case – in my point of view – since it deals with an essentially "perfect" dataset, i.e. all stations observe all seismic events (something which essentially never happens in reality), and even more so with a perfect azimuthal distribution of events, again something which is very unlikely in reality. These limitations are imposed by the authors to probably better be able to gain insight in how the inversion "runs" with a large dataset and how to handle the inversion. This of course doesn't diminish the quality of the paper. Nevertheless, I would have appreciated some synthetic tests with a realistic distribution of data in terms of azimuthal coverage and loss of data for particular stations. Chapter Six, by

far the largest chapter, consists again of a high-class peer-reviewed article. It extends the work presented in chapter five to a realistic case. The authors have chosen the area of central-northern Finland (project LAPNET) for the study for a number of reasons outlined in the paper, one of them being that there exists already a seismic tomography study as well as a study of the seismic anisotropy in the upper mantle. This enables to compare the new results with already existing results and allows to properly judge the resolving power of this new joint analysis and the capabilities of the new code. Included in this paper is also some synthetic modelling based on a real data distribution. As such this chapter is extremely important for the overall "value" of the PhD thesis. Finally, Chapter Seven gives some short concluding remarks and a possible outlook. The seven Chapters are followed by two supplements of published papers of work somehow related to the thesis.

The thesis in general is very well written and very well illustrated with all necessary figures.

The thesis is very novel as it deals with the further development of a widely used code for seismic tomography to include the aspects of seismic anisotropy into the inversion process. While it has been well known for several decades now that the upper mantle in general is anisotropic, it has so far been largely ignored in teleseismic tomography as all the available codes (for short-period body waves) do solve only for the isotropic case. The new code AniTomo shows that making a reasonable number of assumptions concerning the style of anisotropy and its strength based on a large number of observation over the last decades, an anisotropic inversion scheme is feasible and does reduce the ambiguities when jointly invert rather than making a joint interpretation for the velocities and the direction and strength of anisotropy. Therefor this thesis is at the forefront of seismological science and a first step in developing new methods for the huge amount of data getting currently available. It should be stressed that the presented work might trigger more work on jointly analysing wave speeds and anisotropy.

As regarding the candidate: It is obvious that the candidate has a background in physics and mathematics and that the applied method has not been used as a black box. The presented thesis not only shows her thorough knowledge of seismology and computer coding but also insight into the relationship of physical properties, rock structure and the tectonic implications of the results.

The two incorporated papers are both of them of high quality and while they are not the sole work of the candidate, do they nevertheless show with the papers given as supplement the high quality of the candidate to disseminate her research in a clear way to a wider audience.

I believe that the delivered thesis manuscript fully meets the requirements of a dissertation and hence fully support the examination of the candidate on these grounds.