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Review for chapter 5 of the PhD thesis ‘The Structure of the West Bohemian Earthquake Swarm Source Zone’ by Martin Bachura

The PhD thesis by Martin Bachura consist of 7 chapters. After an introduction and a motivation chapter, he describes the geology and seismicity in West Bohemia, the region of his study. Chapter 4 of his study deals with relocations of seismicity observed in the swarm earthquake area. Chapter 5 is a study of seismic attenuation in West Bohemia, whereas chapter 6 deals with an analysis of the V_p/V_s ratio. Chapter 7 contains already published papers, which are results of his PhD thesis. This review report only deals with chapter 5 ‘Coda Attenuation’.

In chapter 5 ‘Coda Attenuation’ Martin Bachura applies three different techniques to analyze seismic attenuation of the Earth’s crust in the West Bohemian earthquake swarm zone for the frequency range 3-24 Hz. The three methods are ‘Coda Window Method’, Multiple Lapse Time Window Analysis’, and ‘Coda Normalization Method’. Sub-chapters 5.1 – 5.3 give a detailed introduction to attenuation of seismic waves and the seismic coda. Sub-chapter 5.4 describes the theory of radiative transfer theory. Sub-chapter 5.5 summarizes some aspects of the Earth’s volume mapped by coda waves and sub-chapter 5.6 deals with coda normalization. Altogether these paragraphs give a good introduction to the theoretical background of the applied methods. Sub-chapter 7 ‘Data’ describes the seismic data used and the data processing applied. The de’scription is comprehensive and adequate. In Sub-chapter 5.8 Martin Bachura describes in more detail the three used techniques to analyze seismic attenuation. For each method a short theoretical introduction and a detailed description of applied data processing is given. Sub-chapter 5.9 summarizes the results of all three methods. The ‘Coda Window Technique’ measures the coda decay rate as a function of frequency. Under the assumption of diffusive S-waves this coda decay rate is interpreted by the author as intrinsic attenuation of S-waves. A power law is fitted to the observed attenuation to describe its frequency dependence. Based on ‘Multiple Lapse Time Window Analysis’ Martin Bachura was able to separate the effects of intrinsic attenuation and scattering attenuation. The result is that intrinsic attenuation dominates over scattering attenuation in the region under study and in the frequency range analyzed. Measurements of intrinsic attenuation well agree with measurements based on ‘Coda Window Technique’. Using the third method, ‘Coda Normalization Method’, the author measures P-wave attenuation as well as S-wave attenuation. However, error bars for P-waves are significantly larger. Results of S-wave attenuation based on this method show slightly higher values than the two other techniques. Sub-chapter 5.10 is a discussion section. Main points here



are possible sources of errors and limitations of the three methods as well as a discussion of the so-called 'leakage effect' and its possible relation to the observed frequency dependence of intrinsic attenuation. Moreover, the author compares the different results of the three methods and compares his results to similar studies in the same region. Sub-chapter 5.11 is a conclusion section for chapter 5 on seismic attenuation.

Altogether, chapter 5 of the thesis is carefully written and sufficiently detailed. Possible sources of error are accurately analyzed. It is specifically interesting that 3 different techniques of attenuation measurement are used and compared. The figures are useful and of good quality. The structure of chapter 5 is logical and the length is adequate. The discussion section is useful and deals with up-to-date problems.

Altogether, Martin Bachura has shown that he is able to analyze complex up-to-date geoscientific problems. **For this reason, I recommend the thesis to be accepted.**

Questions to the candidate:

1) Frequency dependence of observed seismic attenuation

The author states in his thesis that intrinsic attenuation of shear waves in the Earth's crust is frequency independent. Since he observes an apparent frequency dependence in the data, he must find complex mechanisms like the 'leakage effect' to explain it. Is it possible that frequency dependence of seismic shear waves is an intrinsic character of crustal material? Besides olivine, which is more typical for the Earth's mantle, are there other laboratory experiments showing a frequency independence for typical crustal rocks? It might be, that a frequency independence of Q is typical for the Earth's mantle, whereas Q in the crust shows an (intrinsic) power law frequency dependence.

2) Diffusive character of the seismic coda

The author assumes a diffusive character of the seismic coda. It might be interesting to compute the mean free time from the mean free path. Then the lapse times analyzed can be compared to the mean free time. Another interesting question is, whether the diffusion approximation holds, if intrinsic attenuation is dominating over scattering attenuation. One might argue that energy is absorbed before it can be multiply scattered.

3) Leakage Effect

The author claims that coda waves are attenuated in the Earth's mantle ('Leakage Effect'). This leakage effect would clearly exist, if the upper mantle was transparent (much higher scattering Q) or if the upper mantle was strongly attenuating (much lower intrinsic Q). Do we have any independent evidence for one of these characteristics? (The asthenosphere is much deeper and will not cause much leakage.)

These three comments/questions for further research may serve as a stimulation for discussion of the thesis. These questions are at the forefront of research and cannot easily be answered. Moreover, they are only details when compared with the amount and quality of the work done by the author.

Yours sincerely,

(Ulrich Wegler)