Chapter 6

Conclusions and perspectives

The evolution of seismic pulses in random media is studied. For this purpose, we construct the complex, ensemble averaged wave number of an initially plane wave propagating in 2-D and 3-D weakly heterogeneous random media. The validity range of this complex wave number has practically no restrictions in the frequency domain. Its real part is related to the phase velocity dispersion, whereas its imaginary part denotes scattering attenuation. These logarithmic wave field attributes, obtained by combination of the Rytov approximation and the causality principle, are self-averaged quantities and allow to describe any typical, single realization of the wave field. Typical wave field realizations or seismograms are those that are nearly identical to the most probable realization. This approach describes the wave field in the vicinity of the primary arrivals and is an extension of the generalized O'Doherty-Anstey theory of Shapiro and Hubral, (1999). A schematic overview of this approach is provided in Figure (6.1).

In order to calculate the Green's function in 2-D and 3-D random media, we apply a similar strategy as Shapiro and Hubral (1999) for the transmissivities in randomly layered media. Nevertheless, there are some principal differences. In 1-D media the Rytov approximation includes back- and forward-scattering effects. This is not so in 2-D and 3-D random media, where the assumption of forward scattering is necessary in order to simplify the computations. By means of the causality principle we combine the Rytov and Bourret approximations and obtain in this way a wave field description that takes into account at least a part of the back scattering. Moreover, in 1-D media the self-averaging phenomenon leads to a pulse stabilization for larger travel-distances. However, already in 2-D media we can not observe this effect. We explain this by the fact that in contrast to the 1-D case, wave propagation in 2-D/3-D media is characterized by only a partial self-averaging taking place in the weak fluctuation range mainly.

We apply this theory of scattering attenuation to model measured Q-values at the KTB-site using well-log statistics. We find that scattering attenuation plays an important role in the upper crust in this region. Estimates of scattering attenuation as derived from our formulas can be important for further petrophysical interpretations of seismic data from crystalline and reservoir rocks. The Green's function of the primary wave field can be used in order to compensate for transmission losses in the overburden of large-scale reflectors. This is demonstrated with help of numerical tests.

Maybe this work poses more questions rather than giving answers. Nevertheless, I hope that the approach and the results may stimulate further research in the following directions:

- Currently this approach is restricted to isotropic correlation functions. An extension to anisotropic correlation functions should be possible. This is an important issue since real geological structures often show non-isotropic heterogeneities. Other relevant structures for hydrocarbon exploration are cracked and porous media. An extension of our approach based on the poroelastic Biot equations is of great interest.

- The use of the derived Green's function in conjunction with migration techniques is not yet fully exploited. We neglected the phase of the time-harmonic transmissivity and corrected only the amplitude decrease of the primary. However, the phase shift and the corresponding pulse broadening influence the migration result because the summation along the diffraction curves is obviously affected by the wave form. In particular, it is not yet clear in which way our wave field attributes correspond to this summation operation inherent to all migration schemes. For sure, intensive numerical tests are required.

- The new scattering attenuation model can be used in order to interpret measured Q-values from other regions of the lithosphere in the same manner like it is shown for the KTB region. For example, within the collaborative research project SFB 267 Q-estimates extracted from tomography and Multiple Lapse Time Window (MLTW) studies have been obtained and show spatial regions with strong attenuation (see the SFB report 1999-2001 and the references therein). The interpretation of strong attenuation is associated with partial melting due to upgoing fluids released by the subducting ocean plate. It is not yet clear what amount of scattering attenuation can be expected. Using the here presented scattering attenuation model may put some constraints on the magnitude of scattering Q. More precisely, the minimum Q_P-estimates ($Q_P \approx 80$) obtained in the frequency band $0.5 - 8Hz$ can be explained in terms of scattering attenuation using $a = 3km$ and $\sigma_n = 3\%$ for travel-distances $L = 100km$ assuming an exponentially correlated random medium (plug these medium parameters and travel-distance into formula (3.50)). We do not claim to explain all the attenuation in terms of scattering. However, even these hypothetical medium parameters, which are quite usual for stochastic lithospheric models, show that there is a considerable amount of scattering attenuation which should be taken into account.

- There is a possibility to identify signatures of wave localization in 2-D random media in the weak wave field fluctuation regime using the extended ODA approach. More precisely, the so-called wave-correction terms used by Samelsohn et al. (1999) in order to interpret the behavior of wave localization in 2-D random media can be also found with the extended ODA approach.

- The characterization of the coda or at least the early part of it in single realizations of random media remains an open problem. To apply the analytical description of seismogram envelopes to real wave field registrations requires an ensemble of wave field realizations. To overcome this problem is of interest since in many practical situations only a few seismograms are available.

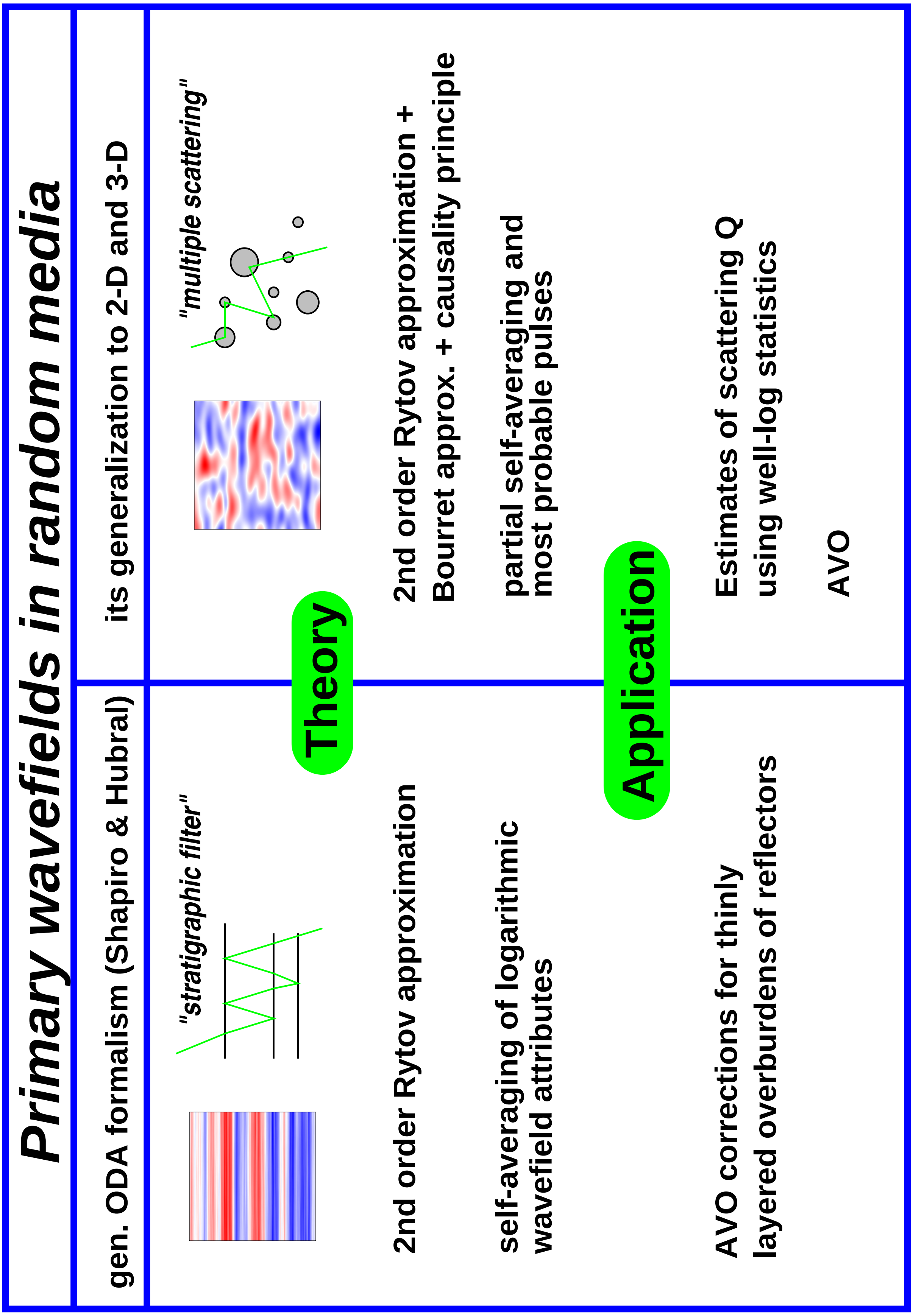

Figure 6.1: The O'Doherty-Anstey approach and its extension to 2-D and 3-D random media at a glance.