Introduction

Report 18 of the Consortium project "Seismic Waves in Complex 3–D Structures" (SW3D) summarizes the work done towards the end of the fourteenth year and during the fifteenth year of the project, in the period June, 2007 — May, 2008. It also includes the DVD compact disk with updated and extended versions of computer programs distributed to the sponsors, with brief descriptions of the programs, and with the copy of the SW3D WWW pages containing papers from previous reports and also from journals.

Consortium project "Seismic Waves in Complex 3–D Structures" has new and simple address **sw3d.cz** of its WWW pages since November 13, 2007.

Our group working within the project during the fifteenth year has consisted of six research workers Václav Bucha, Petr Bulant, Vlastislav Červený, Luděk Klimeš, Ivan Pšenčík, Václav Vavryčuk, and of PhD student Peter Cigánik, who works on the algorithm for stochastic inversion of travel times.

Norman Bleistein (Colorado School of Mines, Golden, USA), José M. Carcione (Osservatorio Geofisico Sperimentale, Trieste, Italy), Klaus Helbig (Hannover, Germany), Einar Iversen (NORSAR, Kjeller, Norway) and Tijmen Jan Moser (Zeebelden Geoservices, van Alkemadelaan, Netherlands) visited us during the period June, 2007 — May, 2008.

Research **Report 18** contains mostly the papers related to inversion techniques (8 of 12 papers) and to seismic anisotropy (4 of 12 papers). Report 18 may roughly be divided into four parts, see the Contents.

The first part, **Seismic models and inversion techniques**, is devoted to various kinds of inverse problems, to the theory developed for application to their solution, and to the construction of velocity models suitable for ray tracing and for application of ray–based high–frequency asymptotic methods.

The first 2 papers of this part, by L. Klimeš, are devoted to the tomographic inversion of travel times. Introductory paper "Computer representation of the model covariance function resulting from travel–time tomography" briefly lists the algorithms we need for numerical realization of the stochastic inversion of travel times. The results of the inversion are represented by the velocity model and the model covariance function. Whereas the velocity model is composed of smooth functions of 3 coordinates, the model covariance function is a function of 6 coordinates with pronounced singularities. The computer representation of the model covariance function in terms of two matrices and the rays used for inversion is designed. The second and extensive paper "Calculation of the a priori geometrical covariances of travel times in a self–affine random medium" is quite technical and presents new equations which make progress in one of the cardinal steps of the stochastic inversion of travel times.

The next 5 papers of this part, by L. Klimeš, are devoted to the inversion of seismograms recorded during a reflection seismic survey. The inversion is based on the Gaussian packets scattered by individual structural Gabor functions. In the previous Report 17, L. Klimeš studied how the perturbations of a generally heterogeneous isotropic or anisotropic structure manifest themselves in the wavefield, and which perturbations can be detected within a limited aperture and a limited frequency band.

He decomposed the perturbations of elastic moduli and density into structural Gabor functions and demonstrated that the wavefield scattered by the perturbations is composed of Gaussian packets scattered by individual structural Gabor functions. The derived approximate solution of the forward scattering problem has been utilized in designing the algorithm of the linearized inversion of the complete set of seismograms recorded for all shots. This challenge of replacing migration by true inversion has represented the main research topic during the period June, 2007 — May, 2008 of the Consortium project. Introductory paper "Stochastic wavefield inversion using the sensitivity Gaussian packets" presents a brief overview of the whole inversion method. Other 4 technical papers present the solutions of individual problems related to small steps in developing the complete inversion algorithm. Paper "Scalar products of the structural Gabor functions" contains the equations required for coding the calculation of the scalar products. Paper "Frame bounds and discretization error of the 1–D Gabor transform" presents the main theoretical result of this part: the new approximate analytic expressions for the frame bounds corresponding to the standard discrete Gabor transform. These expressions can be used to analytically study both the discretization error of the continuous Gabor transform and the stability of the discrete Gabor transform in dependence on the phase–space lattice intervals. Since this theoretical result cannot be practically applied to our wavefield inversion, its considerable but unproved generalization has been conjectured in paper "A conjecture on the frame bounds of the multidimensional Gabor transform with complex–valued envelopes". Paper "Optimization of the structural Gabor functions in a homogeneous velocity model for a zero–offset surface seismic reflection survey" represents a simple attempt to specify the finite set of structural Gabor functions for the wavefield inversion. Specification of the finite set of structural Gabor functions constitutes the first step in our wavefield inversion.

The last paper of this part is devoted to the Gaussian packet prestack depth migration. V. Bucha has continued the work on the Gaussian packet prestack depth migration commenced by K. Žáček in the period 1999–2005. The algorithm of smoothing the parameters describing the shape of optimized Gaussian packets has been modified. The code for optimization has been generalized from the zero offset to the common shot. The code for decomposition of recorded seismograms into Gaussian packets and the code for migration have considerably been sped up. V. Bucha then proceeded to migration with optimized Gaussian packets.

The second part, **Ray methods in isotropic and anisotropic elastic media**, is devoted to the high–frequency methods in general.

Paper "Initial conditions for paraxial ray tracing in inhomogeneous anisotropic media" by V. Červený and T.J. Moser is devoted to paraxial ray methods in the computation of seismic wavefields propagating in elastic media. The basic procedure in paraxial ray methods consists in the solution of dynamic ray tracing equations. The authors derive the initial conditions for dynamic ray tracing equations for the three basic situations: a) initial point situated at an initial curved surface, b) initial point situated at a curved, planar or nonplanar, line, c) isolated initial point (point source). The derived expressions for initial conditions are very general, valid for homogeneous or inhomogeneous, isotropic or anisotropic, media. Along an initial surface and initial line, the travel time may be constant or variable. The results presented in the paper

extend the possible applications in the paraxial ray methods. For example, they will play an important role also in perturbation methods for weakly dissipative media, in which the dynamic ray tracing is needed.

The third part, **Waves in anisotropic attenuating media**, is devoted to the problem of homogeneous and inhomogeneous waves propagating in anisotropic attenuating media. All 3 papers of this part are devoted to perturbation methods from perfectly elastic media to anisotropic attenuating media.

The first paper of this part, "Quality factor Q in dissipative anisotropic media" by V. Červený and I. Pšenčík, is a considerably revised version of the corresponding paper of Report 17. It is devoted to exact and approximate expressions for the quality factor Q of time–harmonic, homogeneous and inhomogeneous plane waves, propagating in unbounded, homogeneous, dissipative anisotropic medium. The direction–dependent quality factor Q is defined as the ratio of the time averaged complete stored energy and the dissipative energy, per unit volume (Buchen 1971). For weakly inhomogeneous plane waves, propagating in weakly dissipative media, the exact expression for Q can be simplified to the approximate one (denoted by $\hat{Q}$), using the perturbation method. Relation of $\hat{Q}$ to the attenuation coefficient α, measured along an arbitrary straight–line profile, is discussed. It is shown that $\hat{Q}$ and α do not depend on the inhomogeneity of the plane wave if the profile is parallel to the ray–velocity vector of the plane wave under consideration. Consequently, the quality factor $\hat{Q}$ is a convenient measure of the intrinsic dissipative properties of rock in the ray direction. Numerical examples are presented.

V. Vavryčuk starts with the knowledge that the real and imaginary parts of the ray–velocity vector corresponding to a point source in a homogeneous anisotropic attenuating medium are parallel, and derives the first–order perturbation expansions from a homogeneous anisotropic elastic medium to a homogeneous anisotropic attenuating medium.

In the third paper of this part, "Perturbation Hamiltonians in heterogeneous anisotropic weakly dissipative media" by V. Červený and I. Pšenčík, the complex–valued travel time and the complex–valued travel–time gradient of seismic body waves propagating in heterogeneous weakly dissipative anisotropic media are studied using the travel–time perturbation theory. The final expressions require simple quadratures along the real–valued reference ray traced in the reference perfectly elastic anisotropic medium. The results are applicable to any type of seismic source, including a point source. This new paper differs from the related paper of the previous Report 17 in the first place by considerably more general forms of the perturbation Hamiltonian, which allow for more accurate perturbation expansions. Attention is also devoted to the special case of an isotropic reference medium.

The fourth and final part, **DVD–ROM with SW3D software, data and papers**, contains the DVD–R compact disk SW3D–CD–12.

Compact disk SW3D–CD–12, edited by V. Bucha and P. Bulant, contains the revised and updated versions of the software developed within the Consortium research project, together with input data related to the papers published in the Consortium research reports. A more detailed description can be found directly on the compact disk. Compact disk SW3D–CD–12 also contains over 330 complete papers from journals

and previous reports in PostScript, PDF, GIF or HTML. Refer to the copy of the Consortium WWW pages on the compact disk. Compact disk SW3D–CD–12 is included in Report 18 in two versions, as the UNIX disk and DOS disk. The versions differ just by the form of ASCII files.

This Introduction is followed by the list of members of the SW3D Consortium during the fifteenth year of the project. We are very pleased to welcome three new Consortium members, NORSAR (Kjeller, Norway), Observatório Nacional (Rio de Janeiro, Brazil), and OMV Exploration & Production GmbH (Wien, Austria). We hope that they will find the membership in our Consortium profitable.

The Research Programme for the current, fifteenth year of the Consortium project comes after the list of members. The Research Programme for the next year will be prepared after the discussion at the Consortium meeting, June 16–17, 2008. More detailed information regarding the SW3D Consortium Project is available online at "http://sw3d.cz".

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