Introduction

Report 19 of the Consortium project "Seismic Waves in Complex 3–D Structures" (SW3D) summarizes the work done towards the end of the fifteenth year and during the sixteenth year of the project, in the period June, 2008 — May, 2009. 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 a new and simple address **sw3d.cz** of its WWW pages since November 13, 2007.

Our group working within the project during the sixteenth 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 stochastic inversion of travel times.

Erika Angerer (OMV, Vienna, Austria), Luís Fernando Chaveiro (State University of Campinas, Campinas, Brazil), Ellen Gomes (Universidade Federal do Pará, Belém, Brazil), Einar Iversen (NORSAR, Kjeller, Norway), Yongxia Liu (Colorado School of Mines, Golden, USA), Amélia Schleicher (University of Campinas, Campinas, Brazil) and Chuntao Zhang (OMV and British Geological Survey, Edinburgh, United Kingdom) visited us during the period June, 2008 — May, 2009.

Research **Report 19** contains mostly the papers related to seismic anisotropy (10 of 14 papers). Report 19 may roughly be divided into six 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 medium correlation function is of principal importance in refraction travel–time tomographic inversion. Travel times measured during refraction seismic experiments contain information on the correlation function primarily in the horizontal directions, whereas sonic–log measurements and vertical seismic profiling in deep wells contain information on the correlation function in the vertical direction. In paper "KTB sonic logs", P. Bulant and L. Klimeš inform us about the available data from sonic–log measurements in the very deep KTB well.

In paper "Gaussian packet prestack depth migration. Part 3: Simple 2-D models", V. Bucha tests the Gaussian packet prestack depth migration in two simple models composed of homogeneous blocks separated by planar or curved interfaces.

Paper "Estimativa da orientacao do eixo de simetria de um meio TI a partir de dados de onda P em experimentos de VSP Walkaway (Estimation of the orientation of the axis of symmetry of TI medium from P–wave data from VSP experiments)" by E. Gomes, S. Silva and I. Pšenčík is the expanded abstract submitted for presentation at the 11th International Congress of the Brazilian Geophysical Society, Salvador, August 24–28, 2009. The paper is devoted to the study of reliability and accuracy of the determination of the orientation of axis of symmetry of the TI medium from polarization and slowness data. Synthetic data, specifically polarization vectors and vertical components

of the slowness vector of direct, reflected or direct and reflected P waves, are used in the experiments. Sensitivity of the results to varying level of noise, configuration, extent of the experiment, etc. is studied. Main conclusion of the synthetic tests is that the results are strongly affected by the quality of the determination of the elastic parameter A_{11}, which controls wave propagation in the horizontal direction.

The second part, **Waves in weakly anisotropic elastic media**, addresses the problems relevant to wave propagation in heterogeneous weakly anisotropic elastic media.

Paper "Shear–wave traveltimes in inhomogeneous weakly anisotropic media" by E. Iversen, V. Farra and I. Pšenčík is the expanded abstract submitted for presentation at the SEG Annual Conference, Houston, October, 25–30, 2009. The paper is devoted to the presentation and tests of approximate traveltime formulae for shear waves in weakly anisotropic media. Traveltimes are computed along first–order common S–wave rays and consist of three parts: first–order traveltime, its second–order correction and the term controlling the separation of shear waves. For models used in the study, with anisotropy varying from 1% to 13%, the relative errors of the approximate formulae are considerably less than 1%.

Paper "Coupled S waves in inhomogeneous weakly anisotropic media using first–order ray tracing" by V. Farra and I. Pšenčík describes continuation of the study of coupled shear waves presented in Report 17. The present paper contains updated, significantly more accurate formulae for computation of coupled shear waves. It also contains results of numerical experiments in models of varying strength of anisotropy. The synthetic seismograms show that the approach can describe not only coupled but also well separated split shear waves.

V. Farra and I. Pšenčík in paper "Transformation of amplitudes at an interface between two inhomogeneous weakly anisotropic media" present expressions for amplitudes of P and coupled S waves reflected or transmitted at a curved interface separating inhomogeneous weakly anisotropic media. The expressions are derived within the concept of first–order ray tracing and dynamic ray tracing.

The third part, **Paraxial ray methods in anisotropic media**, addresses the general theoretical problems of paraxial ray approximation.

In the first paper of this part, L. Klimeš derives the relations between the propagator matrix of geodesic deviation (i.e., paraxial–ray propagator matrix) and the second–order derivatives of characteristic function (i.e., second–order derivatives of two–point travel time) in general coordinates. The equations are applicable to Finsler geometry, to Riemann geometry, and to their various applications like the general relativity or the high–frequency approximations of wave propagation.

Paper "Transformation relations for second derivatives of travel time in anisotropic media" by V. Červený and L. Klimeš is devoted to the second derivatives of travel–time fields in anisotropic media, computed by dynamic ray tracing (DRT) along a reference ray. Two forms of DRT system have been broadly used in applications: the DRT system in global Cartesian coordinates and the DRT system in ray–centred coordinates. Simple transformation relations between the second derivatives of the travel–time field in global Cartesian coordinates and in ray–centred coordinates are derived. These transformation relations can be used in many applications, including the computation of complex–valued paraxial travel times which are necessary in the evaluation of Gaussian beams.

The fourth part, **Gaussian beams in anisotropic media**, is devoted to Gaussian beams in 3–D heterogeneous anisotropic media.

The only paper of this part, "Gaussian beams in inhomogeneous anisotropic layered structures" by V. Červený and I. Pšenčík, is devoted to the theory of Gaussian beams concentrated close to rays of high–frequency seismic body waves propagating in inhomogeneous anisotropic layered structures. The basic role in the computation of Gaussian beams is played by a 2×2 complex–valued matrix of second derivatives of the travel time field along the reference ray. This matrix can be computed in several ways by dynamic ray tracing. Different possibilities are discussed in detail and possible simplifications are outlined.

The fifth part, **Waves in attenuating media**, is devoted to waves propagating in isotropic or anisotropic attenuating media. All 5 papers of this part address the problems related to the calculation of complex–valued travel time.

In real space, the eikonal equation for complex–valued travel time represents the system of two Hamilton–Jacobi equations for the real and imaginary parts of the complex–valued travel time. In paper "System of two Hamilton–Jacobi equations for complex–valued travel time", L. Klimeš suggests to solve these equations numerically using the wavefronts obtained by wavefront tracing.

The numerical solution of the eikonal equation for complex–valued travel time led L. Klimeš to the idea of incorporating the amplitude into the complex–valued travel time. Then the second–order travel–time derivatives are moved from the transport equation to the eikonal equation. This idea is expressed in paper "Complex–valued eikonal–transport equation".

In paper "Description of weak anisotropy and weak attenuation using the first–order perturbation theory", V. Vavryčuk uses the first–order perturbations from an isotropic elastic medium to a weakly anisotropic attenuating medium to approximate the basic wave quantities such as the slowness vector, polarization vector, propagation velocity, and quality factor. He then numerically tests the accuracy of the approximations.

V. Vavryčuk proposed the approximate "real viscoelastic ray tracing" method for the calculation of complex–valued travel time in anisotropic attenuating media. In paper "Real ray tracing in isotropic viscoelastic media: a numerical modelling", he tests this method in the special case of isotropic attenuating media. In this special case, "real viscoelastic ray tracing" reduces to the standard first–order perturbation from real–valued rays calculated for slowness equal to the real part of the complex–valued slowness, using the perturbation Hamiltonian linear with respect to the perturbation parameter. Using the numerical examples in simple heterogeneous isotropic attenuating media, this approach is demonstrated to be very accurate compared to the standard first–order perturbation from real–valued rays calculated for the velocity square equal to the real part of the complex–valued velocity square, using the perturbation Hamiltonian linear with respect to the perturbation parameter.

In paper "The Snell's laws at interfaces in anisotropic viscoelastic media", V. Vavryčuk tests his "real viscoelastic ray tracing" in homogeneous isotropic or anisotropic attenuating media separated by planar interfaces.

The sixth and final part, **DVD–ROM with SW3D software, data and papers**, contains the DVD–R compact disk SW3D–CD–13.

Compact disk SW3D–CD–13, 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–13 also contains over 350 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–13 is included in Report 19 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 sixteenth year of the project.

The Research Programme for the current, sixteenth 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 15–16, 2009. More detailed information regarding the SW3D Consortium Project is available online at "http://sw3d.cz".

We use this opportunity to inform our sponsors about planned workshop on "Seismic waves in laterally inhomogeneous media VII", which will be held at the Castle of Nové Hrady in Czech Republic on June 21–26, 2010. More information can be found at "http://sw3d.cz/swlim/main.htm".

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