Introduction

Report 15 of the Consortium project "Seismic Waves in Complex 3-D Structures" (SW3D) summarizes the work done towards the end of the eleventh year and during the twelfth year of the project, in the period June, 2004 — May, 2005. It also includes the 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.

Our group working within the project during the twelfth year has consisted of six research workers: Václav Bucha, Petr Bulant, Vlastislav Červený, Luděk Klimeš, Ivan Pšenčík and Václav Vavryčuk; and of the PhD student Karel Žáček. Karel Žáček works on the algorithm of Gaussian packet migration. He will defend his PhD thesis on September 21, 2005.

Madjid Berraki (Institut Francais du Petrole, Rueil Malmaison, France), Stefan Buske (Free University Berlin, Germany), Leo Eisner (Schlumberger Cambridge Research, United Kingdom), Veronique Farra (Inst. Physique do Globe de Paris, France), Klaus Helbig (Hannover, Germany), Tijmen Jan Moser (Jason, Amsterdam, Netherlands, 2004; Horizon Energy Partners, 's-Gravenhage, Netherlands, 2005), Robert Patzig (University of Hamburg, Germany), Dirk Rössler (University of Postdam, Germany) and Bjorn Ursin (Tech. University Trondheim, Norway) visited us during the period June, 2004 — May, 2005.

Ivan Pšenčík served as a guest editor of the Proceedings of the 11th International Workshop on Seismic Anisotropy (IWSA) in Newfoundland, August 2004. The Proceedings are to be published in Geophysics.

Just before this year Consortium meeting, we organized an international workshop "Seismic waves in laterally inhomogeneous media VI" at the Castle of Hrubá Skála on June 20–25, 2005. There were 61 participants from 14 countries. They presented 58 oral and poster contributions. Proceedings from the workshop will be published in a special issue of Studia Geophysica et Geodaetica. The special issue will be distributed to the Consortium members.

Research **Report 15** contains mostly the papers related to seismic anisotropy (10 of 13 papers). Report 15 may be roughly 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 paper on the "Decomposition of the wave field into optimized Gaussian packets" by K. Žáček is an extended and revised version of the paper which appeared in Report 13 (2003).

The second contribution by K. Žáček, "Gaussian packet pre-stack depth migration", is mostly new. The short paper in Report 14 (2004) with the equal title contained just preliminary results. The current paper contains brief description of the theory used for the Gaussian packet common-shot migration and a numerical test performed in the Marmousi model. The numerical test includes examples of both a single common-shot migrated section and a stacked common-shot migrated section.

E.N.S. Gomes, I. Pšenčík & J.C. Costa test the efficiency of the inversion scheme for the determination of local anisotropy, proposed in the previous Reports. Using synthetic data, they study the effects of the choice of a reference medium, of the reference wave normal, of the number of sources, etc.

The second part, **Ray methods in isotropic and anisotropic media**, is devoted to the high-frequency methods in general, but does not contain the papers more specifically addressing problems of weak anisotropy or of anisotropic viscoelastic media, which have been postponed to the third and fourth parts. This part also contains a paper describing application of the SW3D ray tracing software distributed on the compact disk.

Manuscript "Seismic Ray Method: Recent Developments" by V. Červený, L. Klimeš & I. Pšenčík has been submitted for publication as a chapter in the book to be titled "Advances in Wave Propagation in Heterogeneous Media", edited by Ru-Shan Wu and Valerie Maupin. The manuscript is devoted to the basic features of the seismic ray method, its recent extensions, and future possibilities. The manuscript gives great attention to kinematic and dynamic ray tracing for S-wave propagation in anisotropic inhomogeneous media. On the other hand, the theory of the summation of Gaussian beams and Gaussian packets is presented for isotropic media only. The authors also address the problem of selecting velocity models appropriate for ray tracing.

In the second paper of this part, V. Červený & T.J. Moser propose a simplified construction of the 4×4 ray propagator matrix in ray-centred coordinates. In this construction, dynamic ray tracing in ray-centred coordinates is not needed, only conventional dynamic ray tracing in Cartesian coordinates is exploited. The 4×4 ray propagator matrix in ray-centred coordinates is then obtained by simple transformations at the initial point of the ray and at any other point of the ray, wherever it is needed.

In the third paper of this part, V. Bucha compares the finite-difference seismograms in the elastic SEG/EAGE Salt Model with the ray-theory seismograms calculated using the SW3D software. The comparison is performed for a selected shot and two receiver configurations.

Contribution "Hamiltonian formulation of the Finsler and Riemann geometries" by L. Klimeš represents the lecture notes prepared for the school "Relativistic Coordinates, Reference and Positioning Systems" held on January 21–25, 2005, in Salamanca, Spain, within the World Year of Physics 2005. For the complete set of lecture notes refer to "http://www.ccr.jussieu.fr/tarantola/Files/Professional/GPS/Proposal.pdf". Application of Hamiltonian ray tracing, dynamic ray tracing and corresponding equations for travel-time perturbations can considerably simplify the equations for the propagation of electromagnetic waves in the general theory of relativity.

In the fifth paper of this part, V. Vavryčuk proposes a method of calculating the slowness vector for a specified ray direction. The method is applicable to general anisotropy of an arbitrary strength having arbitrary complex triplications. The slowness vector is determined by numerical solving a system of three coupled polynomial equations of the 6th order in three unknowns.

The third part, **Weak anisotropy**, addresses the problems relevant to weakly anisotropic media.

In the first paper of this part, V. Vavryčuk demonstrates that the maximum number of isolated acoustic axes in weak triclinic anisotropy is 16, as in strong triclinic anisotropy. The directions of acoustic axes are calculated by solving two coupled polynomial equations of the fifth order in two unknowns. The weak anisotropy approximation is particularly useful, when inverting for anisotropy from the directions of acoustic axes. The minimum number of acoustic axes, which can be inverted for weak anisotropy, is seven, while at most 13 combinations of elastic parameters can be retrieved.

L. Klimeš & P. Bulant present the equations for calculating the second-order perturbation expansion of travel time along the anisotropic common S-wave ray. The second-order terms in the perturbation expansion from the anisotropic common S-wave ray to the anisotropic-ray-theory rays can be used to estimate the errors due to the anisotropic-common-ray approximation of the coupling ray theory. The authors take advantage of their experience with calculating the analogous second-order perturbation expansions along the reference isotropic-ray-theory rays. The contribution is a continuation of the papers of Reports 13 (2003) and 14 (2004) on the anisotropic-common-ray approximation of the coupling ray theory.

The fourth part, **Anisotropic viscoelastic media**, is devoted to the problem of homogeneous and inhomogeneous plane waves propagating in anisotropic viscoelastic media.

In the first paper of this part, V. Červený and I. Pšenčík study the polarization of these waves. It is shown that the polarization is, in general, elliptical. For homogeneous plane waves, the polarization is usually nearly linear, with large eccentricity. The eccentricity decreases with increasing inhomogeneity. Many numerical examples are presented.

In the second paper of this part, again by V. Červený and I. Pšenčík, the properties of the energy flux of these waves are studied. A great attention is devoted to the energy velocity and to the loss factor. Both P and S waves are investigated. Numerical examples are again presented.

The fifth part, **Seismic sources**, is devoted to the forward and inverse problems of source mechanisms, which become increasingly important in reservoir monitoring, especially in connection with hydraulic fracturing.

D. Rössler, I. Pšenčík, F. Krüger & G. Rümpker propose and test an inversion scheme for the retrieval of parameters of a seismic point source situated in an inhomogeneous anisotropic medium. Input data are local seismograms. It is shown that consideration of anisotropy and inhomogeneity of the medium increases substantially quality and reliability of inverted parameters of the source.

The final sixth part, **CD-ROM with SW3D software, data and papers**, contains the CD-R compact disk SW3D-CD-9.

Compact disk SW3D-CD-9, edited by V. Bucha & 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-9 also contains over 220 complete papers from journals and previous reports, mostly in PostScript and GIF, few in PDF or HTML, refer to the copy of the Consortium WWW pages on the compact disk. Compact disk SW3D-CD-9 is included

in Report 15 in two versions, as the UNIX disk and DOS disk. The versions differ just by the form of ASCII files. From new features of the SW3D software, let us mention the calculation of the second-order terms in the perturbation expansion from the anisotropic common S-wave ray to the anisotropic-ray-theory rays, which can be used to evaluate the errors due to the anisotropic-common-ray approximation of the coupling ray theory.

This Introduction is followed by the list of members of the SW3D Consortium during the twelfth year of the project. We are very pleased to welcome a new Consortium member, BP Exploration & Production Inc. (Houston, U.S.A.). We hope BP will find the membership in our Consortium profitable.

The Research Programme for the current, twelfth 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 27–29, 2005. More detailed information regarding the SW3D Consortium Project is available online at "http://sw3d.mff.cuni.cz".

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