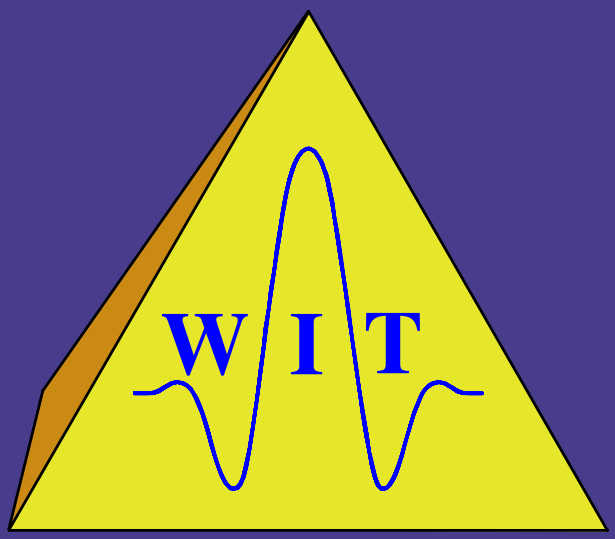
Wave Inversion Technology Consortium



Wave Inversion Technology
established 1997 in Karlsruhe, Germany

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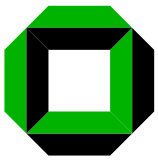


Contents

Preface

2006 has been a very eventful and successful year for WIT with a total of 12 sponsors! Welcome to two new sponsors: Anadarko and Shell. Our researchers were again able to show our partners some interesting research results. The future of the entire consortium was in danger due to the fact, that as of yet, no successor has been found for Peter Hubral. Although he already retired and has his mind set towards the *hidden roots of human discovery and creativity* he has been acting as coordinator for WIT throughout the year. Thanks to Dirk Gajewski's courageous decision to take over the coordination starting in 2007 we are now able to continue WIT and we hope that our sponsors will keep supporting us.

The University of Hamburg successfully defended itself against the offer from the University of Vienna, Austria, to appoint Dirk Gajewski to the chair "Physics of the Earth". The University of Hamburg has established a new chair "Applied Seismics" for Dirk who has been promoted to full professor in the spring of 2006. Moreover, a new staff research position was established for Claudia Vanelle and the whole infrastructure of Dirk's team will be overhauled including some additional financial support.

In November 2006, Martin Tygel celebrated his 60th birthday in conjunction with a remarkable colloquium. Scientists from all over the world came together in Campinas, Brazil for interesting scientific presentations, discussions, and a spectacular festive event.

The work within the WIT consortium has once again been recognized by the scientific community: during their annual meeting in Vienna 2006, the European Association of Geoscientists and Engineers presented the *Nigel Anstey Award* to Eric Duveneck...

> "...in recognition of the importance and originality of his work in the tomographic determination of high-resolution seismic velocity models, using kinematic wavefield attributes extracted from pre-stack data. His approach has led to significant improvements in the efficiency and accuracy of three-dimensional migration and inversion."

Duveneck completed his Ph.D. thesis on this topic in 2004 during his time in the Karlsruhe WIT group and is now with Shell in Rijswijk.

We also congratulate our young WIT-researchers (Ph.D. and M.Sc. students alike) who have successfully completed their studies in 2006. We are happy that almost all of them have found immediate employment with oil companies or contractors.

A note of thanks goes to our associated research group in Belém, Brazil, who has again contributed to the annual report.

We bid farewell from the consortium to Serge Shapiro's group, who is now pursuing other interests. Thank you for the contributions and the excellent cooperation during the last ten years.

We will continue to make waves!

Jürgen Mann

Summary: WIT report 2006

IMAGING

von Steht presents a poststack imaging sequence based on the CRS method for common offset adapted to handle vertical seismic profiling (VSP) walkaway data. A vivid synthetic example is used to visualize the quality of the image after depth migration. Furthermore the CRS-based wavefield separation for multicomponent data is applied for this specific geometry.

Garabito et al tested the performance of VFSA and SA optimization algorithms in Marmousi dataset by using the CRS stacking method. They observed that SA is more robust than VFSA algorithm. The results of the one-step CRS stack present a better resolution (good continuity of reflector horizons) in comparison with the results of the three-steps CRS stacking strategy.

Garabito et al derived a particular traveltime formula for paraxial rays in the vicinity of a central ray associated to a diffraction point in depth. This formula presents a good fitting with respect to the reflected events. They propose this formula as an alternative to simulate Common-Offset (CO) sections. Finally, propose a new strategy to estimate the five parameters in the Finite-Offset (FO) CRS stacking method. For the first third steps use the $SimulatedAnnealing(SA)$ global optimization method. For the fourth step recommend to use the $Quasi - Newton(QN)$ local optimization algorithm.

Meier et al. give a short comparison between two tomographic inversion schemes, namely prestack stereotomography and NIP-wave tomography. The results are compared for a simple synthetic dataset and for a real marine dataset from the Eastern Mediterranean. The differences are discussed with respect to the different inversion approaches.

Kienast presents a real data example for CRS stack based limited-aperture migration in time and depth domain. Kinematic as well as dynamic aspects are considered for time and depth migration, and compared to conventional results.

Klüver presents a new technique for the determination of migration velocity models. The method aims at kinematically fitting common image gathers and common reflection point gathers associated with selected picks in a poststack zero offset section.

Iversen and Tygel present a 3D time-to-depth conversion method that is based on tracing image rays into depth using a given time-migration velocity field. The method can be used both as a mapping scheme (which converts selected events in the time-migrated section into depth) or as an imaging scheme (which converts a time-migrated section into its corresponding full depth migrated section). Although all presented formulas are fully 3D, the method is illustrated in its simpler 2D case.

Ursin and Tygel introduce natural amplitudes for the one-way normal and NIP waves, which provide a useful decomposition of the amplitude of the zero-offset ray. A possible application of the decomposition to a new true-amplitude migration scheme is also described.

Schleicher et al. derive a new image wave equation for remigration in elliptically anisotropic media

by reparameterization of the kinematic expressions. A simple numerical example confirms that this image wave equation, which is a kind of medium-dependent one-way wave equation, can be used to improve well-ties, thus providing an estimate of the vertical velocity.

Anikiev et al. apply a modified diffraction stack method to the problem of source localization. They investigate the localization with known and unknown velocity models.

Vanelle and Gajewski explain how their traveltime-based strategy for true-amplitude migration can be extended to include anisotropy. The new method provides a true-amplitude migrated image without requiring dynamic ray tracing (DRT), which is cumbersome in the presence of anisotropy. A simple example demonstrates that in addition to the depth image, the reconstruction of the reflection amplitudes for anisotropic multi-component data leads to the correct result.

Melo Silva et al. transfer the concepts of true-amplitude one-way wave equations to Gazdag's phase-shift migration. By analytically solving the true-amplitude one-way wave equations in vertically inhomogeneous media, they show that a true-amplitude phase-shift migration consists of the same phase correction as in standard phase-shift migration, plus an amplitude correction that can be applied at each depth level. Simple numerical examples demostrate the improvement of the amplitudes in vertically inhomogeneous media.

Schleicher et al. compare the effects of different imaging conditions for common-shot wave equation migration on the migration artifacts and on the migration amplitudes. The conclude that the most robust imaging condition is one that divides the convolved up- and downgoing wavefields after inverse Fourier transform.

Amazonas et al. show how complex Padé approximations can be used to derive two complex wide-angle pre-stack depth migration algorithms: finite differences (FD) and Fourier finite differences (FFD). These migration methods can handle evanescent waves and have improved impulse responses. The treatment of evanescent waves with the complex Padé approximation stabilizes the FFD algorithm and is more efficient computationally than Biondi's unconditionally stable FFD algorithm.

Yoon et al. applied CRS stack method to seismic reflection data from the North German basin which were recently released by the industry. The land data sets acquired in the early 80ies were reprocessed with the focus on the deeper structures within the basin. The images provide new insight for the sedimentary cover of the basin and for the deeper parts of the crust. The results display an almost flat Moho discontinuity even in the area of the Glückstadt Graben where a lower crustal high density body was discovered. The interpretation is in good agreement with recent results from gravity modeling in this area.

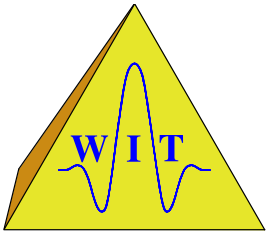
ROCK PHYSICS AND WAVES IN RANDOM MEDIA

Grosfeld and Santos review some of the most used attributes for AVO analysis and introduce a new one based on the reflection impedance function.

OTHER TOPICS

Barbosa et al. extend stereotomography to general anisotropic media and present an implementation for elliptical and anelliptical anisotropy, Numerical examples demonstrate the validity of the present approach for qP events and mild anisotropy, pointing towards the importance of transmission events from multiple-offset VSP experiments for the success of the approach.

The Wave Inversion Technology (WIT) Consortium



The Wave Inversion Technology (WIT) Consortium was established in 1997 and is organized by the Geophysical Institute, Karlsruhe University, Germany. It consists of four fully integrated working groups, one at Karlsruhe University and three at other universities, being the Mathematical Geophysics Group at Campinas University (UNICAMP), Brazil, the Seismics / Seismology Group at the Free University (FU) in Berlin, Germany, and the Applied Geophysics Group (AGG) of the Hamburg University, Germany. In 2003, the Geoscience Center at the University of Pará, Belém, Brazil joined the WIT Consortium as an affiliated working group. The WIT Consortium offers the following services to its sponsors: a) research as described in the topic "Research aims" below; b) deliverables; c) technology transfer and training.

RESEARCH AIMS

The ultimate goal of the WIT Consortium is a most accurate and efficient target-oriented seismic modeling, imaging, and inversion using elastic and acustic methods. Traditionally, exploration and reservoir seismics aims at the delineation of geological structures that constrain and confine reservoirs. It involves true-amplitude imaging and the extrapolation of the coarse structural features of logs onto space. Today, an understanding is emerging on how sub-wavelength features such as small-scale disorder, porosity, permeability, fluid saturation, etc. influence elastic wave propagation and how these properties can be recovered in the sense of true-amplitude imaging, inversion, and effective media. The WIT Consortium has the following main research directions which aim at characterizing structural and stratigraphic subsurface characteristics and extrapolating fine grained properties of targets:

1. data-driven multicoverage zero-offset and finite-offset simulations
2. macromodel determination
3. seismic image and configuration transformations (data mapping)
4. true-amplitude imaging, migration, and inversion
5. seismic and acoustic methods in porous media
6. passive monitoring of fluid injection
7. fast and accurate seismic forward modeling
8. modeling and imaging in anisotropic media

WIT PUBLIC RELATIONS COMMITTEE

Name	University	Area
Peter Hubral	Karlsruhe	WIT headquarters
Claudia Payne	Karlsruhe	WIT headquarters
Jürgen Mann	Karlsruhe	WIT headquarters & WIT report
Alexander Müller	Karlsruhe	WIT report & WIT CD-R
Nicolas Hummel	Karlsruhe	WIT report
Markus von Steht	Karlsruhe	WIT homepage manager

STEERING COMMITTEES

Internal		External	
Name	University	Name	Sponsor
Dirk Gajewski	Hamburg	Roger L. Reagan	Anadarko
Martin Tygel	Campinas	Paolo Marchetti	ENI
Peter Hubral	Karlsruhe	Thomas Hertweck	Fugro Seismic Imaging
Jürgen Mann	Karlsruhe	Paul Krajewski	Gaz de France
Claudia Payne	Karlsruhe	Emil Guberman	Geomage
Jörg Schleicher	Campinas	Dan Grygier	Landmark
Claudia Vanelle	Hamburg	Eduardo Lopes de Faria	Petrobras
Ekkehart Tessmer	Hamburg	Björn Paulsson	P/GSI
		Fons Ten Kroode	Shell
		Pierre-Alain Delaittre	Total
		Henning Trappe	TEEC
		Alfonso Gonzalez	Western Geco

COMPUTING FACILITIES

In Karlsruhe, the research project uses computer facilities that consist of mainly Hewlett-Packard (HP), Silicon Graphics (SGI), and Linux workstations. These are networked with a local compute server, a SGI Origin 3200 (6 processors, 4GB shared memory). For large-scale computational tasks, an IBM RS/6000 SP-SMP (256 nodes + 52 nodes) and a Fujitsu VPP 5000 are available on campus. If there is still a request for more computing power, a Cray T3e (512 nodes), a NEC SX-4/32, and a Hitachi SR8000 (16 nodes) can be used via ATM networks at the nearby German National Supercomputing Center (HLRS) in Stuttgart.

The Hamburg group has access to a 16 nodes (8 CPUs and 8 GB each) NEC SX-6 supercomputer at the German Computer Center for Climate Research (Deutsches Klimarechenzentrum, DKRZ) for numerically intensive calculations. Additional computer facilities consist of several SUN workstations and Linux PCs.

The Geophysical Department of the Free University of Berlin has excellent computer facilities based on Sun- and DEC-Alpha workstations and Linux PCs. Moreover, there exists access to the parallel supercomputer Cray T3m (256 proc.) of ZIB, Berlin.

The research activities of the Campinas Group are carried out in the Mathematical Geophysics Laboratory. The Lab has many PC Linux workstations and Sun Ultra 60/80 workstations connected by a dedicated network, suitable for parallel processing. For large-scale applications, the Lab has full access to the National Center for High Performance Computing of São Paulo, that maintains, among other machines, an IBM RS/6000 9076-308 SP (43 nodes) with 120GB of RAM. Also available are seismic processing software packages from Paradigm and CGG.

The main computing facility at the Geophysics Graduation Program in Belém is the Seismic Processing Lab (ProSis). The hardware resources include: workstations (RS3600) from IBM and a SUN SparkStation 20, all networked to a local server SUN Enterprise-3500 with 2 processors; several networked Linux-PCs; for large-scale applications, a cluster of PCs with 20 dual-processor nodes. The proprietary software packages available for seismic applications are ProMAX, Disco-Focus, and Gocad.

WIT research personnel

Mikhail Baykulov received his diploma in geophysics in 2004 from Saratov State University, Russia. He confirmed his diploma in 2005 at the University of Hamburg with a thesis on the "Application of the CRS stack to reflection data from the crystalline crust of Northern Germany". Since 2005 he has been a Ph.D. student at the University of Hamburg. His present research interests include CRS imaging, migration velocity analysis, and depth inversion applied to deep seismic reflection data.

Ricardo Biloti received his BSc (1995), MSc (1998) as well as PhD (2001) in Applied Mathematics from the State University of Campinas (UNICAMP), Brazil. Since May 2002, he has been working for Federal University of Paraná (UFPR), Brazil, as an Adjoint Professor at the Department of Mathematics. Nevertheless he is still a collaborator of the Campinas Group. His research areas are multiparametric imaging methods, like CRS for instance. He has been working on estimating kinematic traveltime attributes and on inverting them to construct velocity models. He is also interested in Numerical Analysis, Numerical Linear Algebra, and Fractals. He is a member of SBMAC, SIAM, and SEG.

Stefan Buske received his diploma in geophysics (1994) from Frankfurt University. From 1994 until 1998, he worked as research associate at Frankfurt University, and from 1998 until 1999 he was with Ensign Geophysics Ltd. (Depth Imaging Department) in London. Since 1999 he is a university staff member at the Free University of Berlin. His research interests include seismic modeling and inversion, deep seismic sounding and parallel programming. He is a member of EAGE, SEG, AGU, ASA and DGG.

Klaus Mairan Laurido do Carmo received his BSc (2001) in Mathematics from the Federal University of Pará (Brazil). Presently, he is finishing his master's thesis entitled "Global Optimization methods applied in the search of the 2-D CRS stack parameters" at Federal University of Pará. His research interest is Applied Mathematics.

Daniel Chalbaud received his degree as Geophysical Engineer from Universidad Simon Bolivar (Caracas, Venezuela) in 2000. He worked in the Seismology Department of the Venezuelan Institute for Seismological Research (FUNVISIS). Also, he worked as Explorer Geophysicist for the Geophysical Data Acquisition Department of the Venezuelan Oil Company (PDVSA). Currently, he is working as a Ph.D student at Freie Universitaet Berlin. His research interests focus on seismic data processing, imaging and seismic data acquisition. Member of the SEG and SOVG.

Pedro Chira-Oliva received his MSc in 2000 and PhD in 2003 from Federal University of Pará (Brazil), both in Geophysics. His research interests are macro-model independent imaging methods, seismic image wave methods and 3D modeling. He is a member of SBGf and SEG.

Jessé Carvalho Costa received his diploma in Physics in 1983 from the Physics Department, Federal University of Pará (UFPA) and a Doctor degree in Geophysics in 1993 from the Geophysics Department at the same University. He was a Summer Student at Schlumberger Cambridge Research in 1991 and 1992. He spent 1994 and 1995 as a post-doc in the Stanford Tomography Project at Stanford University. He held a faculty position the Physics Department at UFPA from 1989 to 2003. Currently his is Associate Professor in the Geophysics Department, UFPA. His fields of interest include seismic anisotropy, traveltime tomography and seismic modeling.

João Carlos Ribeiro Cruz received a BSc (1986) in geology, a MSc (1989), and a PhD (1994) in geophysics from the Federal University of Pará (UFPA), Brazil. From 1991 to 1993 he was with the reflection seismic research group of the University of Karlsruhe, Germany, while developing his PhD thesis. Since 1996 he has been full professor at the geophysical department of the UFPA. His current research interests include velocity estimation, seismic imaging, and application of inverse theory to seismic problems. He is a member of SEG, EAGE, and SBGF. Actually, he is the Director of the National Department of the Mineral Production of the Pará Province.

Stefan Dümmong received his diploma in Geophysics in 2006 from the University of Hamburg. Since 2006 he is PhD student in the department of Applied Geophysics at the University of Hamburg. His research interests are imaging procedures and multiple removal techniques. He is a member of EAGE.

Jaime Fernandes Eiras received his diploma in geology in 1975 from the Pará University, Brazil. He joined Petrobrás in 1976, where he worked as a wellsite geologist until 1983, and as an exploration geologist until 2001. Since March 2002, he has been a visiting professor at the Geophysics Department of the ParÚniversity. As a basin interpreter, he has studied many of Brazil's offshore and onshore areas, such as Atlantic-type, paleozoic, rift, and multicyclic basins. His fields of interest are structural, stratigraphic, and seismic interpretation, especially seismic stratigraphy. He is a member of the Brazilian Geological Society.

Carlos A.S. Ferreira received a BSc (1996) and a MSc (2000), both in physics, at Federal University of Pará. From 1997 to 2001, he spent some time studying geology, where he had the opportunity of working with some geophysical methods, such as vertical electric sounding and well logging, both as a geology graduate student. Presently, he is working towards his PhD in geophysics at Federal University of Pará, where the main topic of his thesis is prestack depth migration using Gaussian beams. His main research interests are quantum description via Ermakov invariants (in physics) and all forward and inverse seismic imaging techniques. He is member of SEG, SBPC and SBGf.

Dirk Gajewski received a diploma in geophysics in 1981 from Clausthal Technical University and a PhD from Karlsruhe University in 1987. Since 1993, he has been associate Professor (Applied Geophysics) at Hamburg University. After his PhD, he spent two years at Stanford University and at the Center for Computational Seismology at the Lawrence Berkeley Lab in Berkeley, California. From 1990 until 1992, he worked as an assistant professor at Clausthal Technical University. His research interests include high-frequency assymptotics, seismic modeling, and processing of seismic data from isotropic and anisotropic media. Together with Ivan Psencîk, he developed the ANRAY program package. He is a member of AGU, DGG, EAGE, and SEG, and serves as an Associate Editor for Geophysical Prospecting (section anisotropy).

German Garabito received his BSc (1986) in Geology from University Tomás Frias (UTF), Bolivia, his MSc in 1997 and PhD in 2001 both in Geophysics from the Federal University of Pará (UFPA), Brazil. Since 2002 he has been full professor at the geophysical department of UFPA. His research interests are data-driven seismic imaging methods such as the Common-Refection-Surface (CRS) method and velocity model inversion. He is a member of SEG, EAGE and SBGF.

Ellen de Nazaré Souza Gomes received her diploma in Mathematics in 1990 from University of Amazônia. She received her Master degree in Applied Mathematics in 1999 from the Mathematics Departament, Federal University of Pará. In 2003, she received her Doctor degree in Geophysics from Geophysics Department at the same University. Her fields of interest are anisotropy and seismic modeling. She has been professor at the Federal University of Pará since 1997.

Kolja Gross studied physics at the Freie Universität Berlin and received his diploma in 2004. Since April 2004 he is working as a Ph.D. student on reflection seismic data. His research interests include seismic modeling, imaging techniques and scattering.

Zeno Heilmann received his diploma in Geophysics from the University of Karlsruhe (TH) in October 2002. Since November 2002 he has been a research associate at the Geophysical Institute, Karlsruhe University. Besides the practical application of the CRS stack based imaging workflow in several research projects, he works on the development of the CRS stack software, focusing on the influence of rugged topography and near surface velocity variations. He is a member of EAGE and SEG.

Peter Hubral received an M.Sc. in 1967 in geophysics from Clausthal Technical University and a Ph.D. in 1969 from Imperial College, London University. Since 1986, he has been a full Professor of Applied Geophysics at Karlsruhe University specialising in Seismic Wave Field Inversion. During 1970-73 he was with Burmah Oil of Australia and from 1974 to 1985 he was with the German Geological Survey in Hannover. He was a consultant in 1979 with AMOCO Research and, during 1983-1984, a Petrobras-sponsored visiting professor in the PPPG project at the Universidade Federal da Bahia in Brazil. In 1995-1996 he was an ELF- and IFP-sponsored visiting professor at the University of Pau, France. He received EAEG's Conrad Schlumberger Award in 1978, the SEG's Reginald Fessenden Award in 1979, and the EAGE's Erasmus Award in 2003. He is a regular member of DGG and an honorary member of the EAEG/EAGE and SEG. Peter Hubral is involved in most of WIT's activities, in particular those including research on image resolution, image refinement, image attributes, multiple suppression, incoherent noise suppression, true-amplitude imaging, interpretative processing, and image animation.

Florian Karpfinger is a diploma student. Presently, he is working at the reservoir characterization group at the Free University Berlin. He is a member of the SEG, DGG, and EAGE.

Boris Kashtan obtained his MSc in theoretical physics from Lenigrad State University, USSR, in 1977. A PhD (1981) and a Habilitation (1989) were granted to Boris by the same University. He is Professor at St. Petersburg State University, Russia, and since 1996 Boris is head of the Laboratory for the Dynamics of Elastic Media. His research interests are in high frequency methods, seismic modeling, inversion, anisotropy, and imaging. He regularily visits Germany and spends from weeks to several month at the University of Hamburg every year.

Mareike Kienast is diploma student at the Geophysical Institute of Karlsruhe. She is currently working on the application of limited-aperture migration. She is a member of EAGE.

Tilman Klüver received his diploma (with distinction) in geophysics from Karlsruhe University in February 2004. Since April 2004, he has been a research associate at Karlsruhe University. His research covers the application of kinematic wavefield attributes in 2D and 3D inversion schemes as well as their extraction from seismic datasets. He is a member of the EAGE and the SEG.

Oliver Krüger received his diploma in geophysics in 2002 from Freie Universität Berlin and is currently a PhD student at Freie Universität Berlin. His research interests focus on finite difference modeling, imaging and property prediction of fractured materials.

L.W.B. Leite is a professor of geophysics at the Graduate Course in Geophysics, and member of the Department of Geophysics of the Federal University of Pará (Belem, Brazil). His main emphasis at the present time is seismic wave propagation in thin layers for deconvolution and inversion problems.

Rômulo Correa Lima received his diploma in geophysics in 2002 from Geophysical Department of the Federal University of Pará, Brazil, with a thesis on Seismic Migration. In 2002 and 2003, he was a researcher in the seismic group of that university. Currently he is working on 3D modeling.

Jürgen Mann received his diploma in geophysics in 1998 from the Faculty of Physics, Karlsruhe University, with a thesis on Seismic Image Waves. In 2002, he received a doctorate in natural sciences (with distinction), again from the Faculty of Physics in Karlsruhe, with a thesis on the Common-Reflection-Surface Stack method. Since 1998 he has been a research associate at Karlsruhe University, since 2001 he is assistant to Prof. Peter Hubral. His fields of interest are seismic reflection imaging methods, especially

data-driven approaches based on kinematic wavefield attributes. He is active member of the SEG, member of the EAGE and its research committee, and member of the editorial board of the Journal of Seismic Exploration.

Kristina Meier is a diploma student in Geophysics at the University of Hamburg. Her research interests are seismic imaging and velocity model building in random media. Currently, she is working with different tomographic inversion approaches. She is a member of EAGE.

Nils-Alexander Müller received his diploma in geophysics in December 2003 from Karlsruhe University, Germany. His thesis dealt with the implementation of the 3D CRS stack. Since 2004 he has been a research associate at the Geophysical Institute in Karlsruhe. His research covers the 3D CRS stack and the application of the kinematic wavefield attributes in 3D inversion algorithms. Alex is also responsible for the WIT report. He is a member of EAGE and SEG.

M. Amélia Novais received her M.Sc. in Mathematics from the Brazilian Institute of Pure and Applied Mathematics (IMPA) in 1993 and her PhD in Applied Mathematics from State University of Campinas (Unicamp) in 1998. Since 1996, she has been a professor for Mathematics at the Federal University of Sao Carlos (UFSCar), Brasil. She has joined Unicamp in April 2002. Her research interests focus on partial differential equations and include seismic forward imaging. In particular, she works with finite differences to obtain the solution of the acoustic and elastic wave equation, as well as with the Born and Kirchhoff approximations. Presently, she also studies image-wave equations. She is a member of SEG, EAGE, SBGf, SBMAC, and SBM.

Claudia Payne has been Peter Hubral's secretary since 1990. She is in charge of all WIT administrative tasks, including advertising, arranging meetings, etc. Email: Claudia.Payne@gpi.uka.de; phone: +49-721-608-4443, fax: +49-721-71173

Rodrigo Portugal received his B.Sc. (1995), M.Sc. (1998), and PhD (2002) in Applied Mathematics from the State University of Campinas (UNICAMP), Brasil. In his thesis he studied wavefront construction in the 2.5D situation and its application to the four Kirchhoff operations, namely: modeling, migration, demigration and demodeling. Currently he is an associate researcher of the Department of Geology and Natural Resources (DGRN) at UNICAMP. His research interests include wavefront propagation, numerical analysis, seismic imaging and inversion.

Lasse Rabenstein is a diploma student. He is currently working as a teaching assistant for the department of Geophysics at the FU Berlin. His interests are seismic imaging and wave phenomena in random media.

Susanne Rentsch received her diploma in geophysics from the Free University Berlin in July 2003. Her diploma thesis was about "Hydraulic characterization of rocks using density of microseismicity". Since August 2003 she has been working as a PhD student on location of seismic events using imaging techniques.

Elmar Rothert received his diploma in Geophysics in 1999 from the University of Göttingen. In his diploma thesis he studied the scattering of teleseismic waves at small-scale heterogeneities in the crust and lithosphere below the seismic receiver array GRF in Germany. Since January 2000 he is a Ph.D. student of Prof. Shapiro at the Freie Universität Berlin. Currently, he focuses on the reconstruction of permeability in heterogeneous, anisotropic, fluid-saturated media from induced microseismicity. He is a member of AGU, EAGE, and SEG.

Erik Saenger received his diploma in Physics in March 1998 and his Ph.D. in November 2000 from the University of Karlsruhe. Since January 2001 he has been a research associate at the Freie Universität Berlin. Currently, he focuses on Finite Difference modeling of fractured materials at the Geophysical Institute, Free University Berlin. He is member of the DGG, DPG, SEG, and EAGE.

Lúcio Tunes Santos received his B.Sc. (1982) and M.Sc. (1985) in Applied Mathematics from the State University of Campinas (UNICAMP), Brazil. In 1991 he earned his PhD in Electrical Engineering also from UNICAMP. From 1985 to 1988 he was employed as a Teaching Assistant at the University of Sao Paulo (USP). Since 1988 he has been working for UNICAMP, first as an Assistant Professor and after 1999 as an Associate Professor. From 1994 to 1995 he visited Rice University as a postdoc researcher and in 1998, 1999 and 2001 he was a visiting professor at the Geophysical Institute of Karlsruhe University (Germany). His professional interests include seismic modeling and imaging as well as nonlinear optimization and fractals. He is a member of SBMAC (Brazilian Society of Computaional and Applied Mathematics) and SEG. His present activities include the development of new approximations for the P-P reflection coefficient, alternative attributes for AVO analysis, and finite-difference methods for the eikonal and transport equations.

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