# Wave Inversion Technology Consortium

Wave Inversion Technology
established 1996 in Karlsruhe, Germany

## Annual Report No. 16
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*Institute of Geophysics*
*University of Hamburg*

*Hamburg, Germany*

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# Contents

# Preface

It has been sixteen years since the foundation of WIT, and our motivation for leading edge research in applied seismics as well as educating the next generation of geophysicists is unbroken. In this new issue of the annual report, we present our most recent scientific contributions.

The report itself, however, covers 'only' a fraction of what we are and what we have achieved during the past year. Before you, dear reader, start digging into the contents, we would, therefore, like to share some other good news with you.

In March 2012, the Hamburg Institute of Geophysics hosted the annual meeting of the German Geophysical Society (DGG). Almost 600 participants enjoyed the more than 400 contributions and the scientific exchange.

In the framework of the DGG meeting, we are particularly pleased to announce that two WIT researchers, Mehrnoosh Behzadi, doctoral student in Hamburg, and Sven Heider, doctoral student in Karlsruhe, were honoured with the best poster and best oral presentation, respectively, awards for young scientists.

The DGG meeting was not the only convention in 2012 where WIT made an impact. At the annual SEG and EAGE conferences, as well as the 15th International Workshop on Seismic Anisotropy (15IWSA), WIT scientists impressed their audiences with twenty-four presentations spanning the whole research portfolio of our consortium. As an outcome of 15IWSA, a special section will be published in GEOPHYSICS and Claudia Vanelle and Dirk Gajewski serve as guest editors of this volume. Furthermore, Thomas Bohlen from Karlsruhe was invited to give the Gauss lecture at the EGU meeting in Vienna where he presented his work on "Where no wave has gone before: unconventional elastic wave fields in exotic regimes".

Mehrnoosh Behzadi and Sven Heider are by far not the only thriving young WIT researchers. Andre Kurzmann (Karlsruhe), Sergius Dell (Hamburg), and Jadsom de Figueiredo Campinas) successfully defended their Ph.D. theses in 2012. In addition, Claudia Vanelle achieved her habilitation with a thesis on "Stacking and migration in an/isotropic media". Furthermore, we had the pleasure to perform research with a number of excellent M.Sc. and B.Sc. students. Some of these works are so inspiring that we decided to include them in this report.

Altogether, you can find twenty-one contributions in the report. The majority of these, ten papers, detail recent research in imaging, ranging from investigations of new, nonhyperbolic multi-parameter stacking operators to enhanced imaging using diffractions, but not restricted to these topics. Six papers deal with new advances in the dynamic field of full waveform inversion. The remaining five works address modeling and other topics.

The WIT report is issued once a year. If you wish to keep up with recent developments in our research, we are proud to announce that we have launched a "Research News" section on the WIT website. Here, we publish our latest results exclusively for you.

All of these successes would not have been possible without your sponsorship. It is worth a remark that the WIT project funded by private enterprises is the longest lasting project in my career. It allows us to exhibit a continuity in our research not possible with any kind of public funding which lasts just a few years but not decades. It is only through your continued support that we are able to pursue our mission: to perform leading edge research in applied seismics and to educate the next generation of geophysicists.

Hamburg, 2013/18/02, Dirk Gajewski

# Summary: WIT report 2012

### IMAGING

**Bauer et al.** extend the i-CRS multi-parameter stacking operator to converted waves and investigate it with two different parametrizations. The resulting three and five parameter operators are subject to several numerical studies in simple generic models in order to examine their traveltime accuracy and their ability to estimate the optimization parameters. A comparison that also considers a hyperbolic operator reveals the superiority of the new non-hyperbolic five parameter operator.

**Bobsin et al.** investigate a four parameter extension of the i-CRS formulae. The fourth parameter is the overburden velocity. Accuracy and sensitivity studies show an improved behavior in terms of traveltime accuracy and sensitivity towards the kinematic wave field attributes in comparison with CRS, MF abd i-CRS (three parameter). The application as a stacking operator leads to comparable results with the three parameter i-CRS.

**Coimbra et al.** discuss the use of the focusing of remigration trajectories starting at incompletely migrated diffraction events for seismic diffraction imaging and velocity model improvement. The method uses an approximate velocity model as input. It provides diffraction locations in the depth domain and information about the average velocity model which can be converted to interval velocities. They demonstrate the feasibility of the method using synthetic data examples from three simple constant-gradient models and the Sigsbee2B data.

**Coimbra et al.** introduce a data-driven stacking technique that transforms 2D/2.5D prestack multi-coverage data into a stacked common-offset (CO) section, referred to as OCO stack. The method combines offset continuation with stacking techniques to allow for the a horizon-based velocity analysis method, where root mean square (RMS) velocities and local event slopes are determined by stacking along event horizons.

**Faccipieri et al.** propose a combined approach in which the conventional CRS stack is superimposed by a CRS diffraction-enhanced stack in such way that we can recover the diffractions attenuated in CRS stacked sections. Such a combination will ensure, not only a signal-to-noise enhanced stack, but also preservation of finer diffraction details. The proposed approach has been tested with good results employing marine seismic data acquired offshore Brazil.

**Gelius et al.** address the question of how to form a high-resolution image of diffracted wave contributions in seismic reflection data. Straightforward use of migration type of reconstruction methods will not be able to preserve the fully resolving power of diffractions, due to the diffraction-limit conditions inherently attached to those approaches. We propose a new high-resolution imaging technique based on a windowed or steered MUSIC implementation. Application of the method on both synthetic and field data demonstrated a resolving power beyond that of standard migration.

**Pronevich et al.** suggested a new traveltime approximation of diffracted waves for general anisotropic media. The traveltime expression formulated as a double-square-root equation that allows to accurately and reliably describe diffraction traveltimes. Numerical examples and application of the method to a synthetic data set demonstrate how the new approximation work.

**Takahata et al.** review key topics associated with deblurring of prestack depth migrated seismic images based on the use of resolution functions and propose an approach based on regularized 2D spiking deconvolution. The potential of this technique is illustrated by the use of synthetic data.

**Vanelle and Gajewski** extend their traveltime-based strategy for amplitude-preserving migration to anisotropic media. The required Greens functions are generated using only traveltimes. This has the advantage that dynamic ray tracing methods with their high demand on model smoothness need not be applied. Examples demonstrate the quality of the high image quality as well as the accuracy of the reconstructed reflection amplitudes.

**Vanelle et al.** extend the i-CRS operator to account for the presence of seismic anisotropy. They demonstrate that the new operator leads to a highly accurate traveltime description. Furthermore, they conclude that the estimation of anisotropy parameters with the i-CRS operator has high potential.

## MODELING

**Bloot et al.** use the theory of vector-field decomposition with the purpose of solving the VTI elastic wave equation in a homogeneous medium. The result is an elegant generalization of known facts of the classic isotropic case, particularly Helmholtz decomposition into decoupled wave equations for P and S waves.

## FULL WAVEFORM INVERSION

**Dunkl** explains the implementation of a 3D elastic full waveform inversion. Random medium model data is inverted with different acquisition geometries, and a comparison to 2D full waveform inversion is shown.

**Groos et al.** investigate the influence of the initial P-wave velocity model on the reconstruction of the S-wave velocity model in a full waveform inversion (FWI) of shallow seismic Rayleigh waves.

**Heider et al.** show some necessary steps to invert for the fiel data. These steps are tested with a synthetic random distributed velocity model.

**Macedo et al.** study a decomposition based on scattering theory that allows to break the acoustic-wavefield sensitivity kernels with respect to model parameters into background and singular parts. Their numerical results show that those subkernels can be used to backproject the scattered residual only into model space and obtain background-model perturbation estimates. In an experiment with restricted acquisition geometry (reflection data, narrow offset), the multiple-scattering subkernels take advantage of medium self-illumination provided by the scattered wavefields.

**Przebindowska et al.** investigate the influence of the parameter choice describing the medium on the multi-parameter acoustic inversion of marine reflection seismics.

**Schäfer et al.** discuss effects of geometrical spreading corrections towards 2D full waveform inversion of shallow seismic surface waves.

## OTHER TOPICS

**Marcondes et al.** built two physical anisotropic model, acquired ultrasonic measurements under varying stress level, and analysed the results. They show the relationships between seismically derived elastic parameters and fracture parameters. On the basis of this information from rock samples or analogous models, or even cross-well data, it might be possible to characterize the properties of a fractured reservoir or even figure out which regions of a reservoir are more extensively fractured.

**Morelatto and Biloti** make an analysis of the structure tensor ability to estimate local slopes on

2D seismic data, in order to perform structure enhancing filtering. They compare this method to two different methods of slope estimation using plane-wave destruction.

**Raub et al.** discuss the influence of the dynamic ocean on the imaging of the water column. The investigation is quantified by a synthetic modeling study considering an ocean model close to the Strait of Cardiz. The images of the water column may show only very little similarities depending on acquisition time. Particularly the lateral extent of imaged structures highly depends on the acquisition direction with respect to the flow of water masses.

**Werning and Gajewski** show the effects of a dynamic ocean on time-lapse seismic data of the subsurface. Synthetic data are used for this study. The influence on the repeatability of the data is discussed.

# The Wave Inversion Technology (WIT) Consortium

**Wave Inversion Technology**
**established 1996 in Karlsruhe, Germany**

The Wave Inversion Technology Consortium (WIT) was established in 1996 and is organized by the Institute of Geophysics of the University of Hamburg. It consists of three integrated working groups, one at the University of Hamburg and two at other universities, being the Mathematical Geophysics Group at Campinas University (UNICAMP), Brazil, and the Geophysical Institute of the Karlsruhe University. In 2003, members of the Geophysical Department at the Federal University of Pará, Belém, Brazil, have joined WIT as an affiliate working group. In 2007, NORSAR joined WIT as research affiliate. In 2010, Fraunhofer ITWM joined WIT as research affiliate.

The WIT Consortium offers the following services to its sponsors:

a.) research as described below;

b.) deliverables;

c.) technology transfer and training.

The ultimate goal of the WIT Consortium is a most accurate and efficient target-oriented seismic modelling, imaging, and inversion using elastic and acoustic methods. Within this scientific context it is our aim to educate the next generations of exploration geophysicists.

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 into space. The goals on seismic resolution are constantly increasing which requires a complementary use of kinematic and wave equation based techniques in the processing work flow. At WIT we use a cascaded system of kinematic and full wave form model building and imaging techniques. Since our data and inversions are never perfect it is the challenge to find those techniques which produce the best images for erroneous velocities and faulty wave forms.

## RESEARCH TOPICS

The WIT consortium has the following main research directions, which aim at characterizing structural and stratigraphic subsurface properties. Some of the topics are studied by more than one team, applying different approaches. The WIT research is divided into five subgroups:

### Processing and Imaging

The Common Reflection Surface (CRS) concept plays a key role in the WIT research on processing and imaging. The WIT hyperbolic CRS and non-hyperbolic i-CRS stacking operators are based on this concept and represent the backbone of many research topics.

- wavefield decomposition using stacking attributes (reflections, diffractions)
- high resolution diffraction and local reflection imaging
- development and application of non-hyperbolic double square root multi-parameter stacking operators applicable at long offsets
- i-CRS converted wave processing and stacking for anisotropic media
- i-CRS super gather implementation, data interpolation and regularization
- improved coherence measures (MUSIC, cross-correlation, analytical trace, etc.)
- optimization of multi-dimensional coherence analysis
- hardware: FPGA, massive parallel
- software: multi-dimensional optimization, data management
- methodology: initial CRS attributes from local slopes
- data driven isotropic and anisotropic time migration
- multiple suppression in the time migrated domain (CSP-gathers)
- CRS and diffraction processing of 3-D hard rock data
- angle domain migration
- image wave re-migration
- migrated-domain CRS methods

### Model Building

Most of our model building approaches also exploit the CRS concept, which may be applied in the data or time migrated domain.

- diffraction focusing velocity analysis
- passive seismic data velocity model update
- data driven i-CRS anisotropic parameter estimation
- CRS based time to depth conversion
- migration velocity analysis and velocity model building from local slopes
- tomographic inversion of stacking attributes

### Full Waveform Inversion

Research on Full Waveform Inversion (FWI) is moving towards the applications to field data, e.g. industry marine reflection seismic data, near surface multi-component data, and multi-component data in crystalline rocks.

- development of data preprocessing for FWI
- strategies for 2-D/3-D visco-elastic multi-parameter FWI (P-velocity, S-velocity, density, Qp, Qs)
- source wavelet inversion (marine, near surface or hard rock data)
- spreading corrections for body waves and surface waves
- implementation of time-domain and time-frequency domain 2-D and 3-D acoustic/elastic/viscoelastic FWI on HPC machines

### Modeling and RTM

In modeling and RTM we use FD and pseudo spectral approaches. Optimizations of the computational effort is highest on the agenda.

- 2-D and 3-D RTM for VTI and TTI media (spectral methods)
- 2-D and 3-D acoustic and elastic RTM (FD methods)
- Computational optimizations of FD and spectral method approaches for acoustic, elastic, and anisotropic media, including benchmarking
- improved one-way wave equation
- reflection impedance description of reflection coefficients
- tuning effects in AVO and AVA

### Passive Seismics

Passive seismic signals as a diffraction event provide the link to reflection seismics. Located diffractions or micro-earthquakes provide natural Green's functions for reflection imaging.

- optimization of model-domain stacking and correlation based localization approaches
- high resolution full waveform relative event localization
- microtremor localization
- interferometric re-localization
- development of fast time-domain localization technique
- localization uncertainties (apertures, velocities, bandwidth, acquisition footprint)
- real time processing methodology

# WIT STEERING COMMITTEES

## Internal Steering Committee

| Name | WIT team |
|---|---|
| Thomas Bohlen | Karlsruhe |
| Norman Ettrich | ITWM |
| Dirk Gajewski | Hamburg |
| Stefan Jetschny | Karlsruhe |
| Tina Kaschwich | NORSAR |
| Jörg Schleicher | Campinas |
| Martin Tygel | Campinas |
| Claudia Vanelle | Hamburg |

## External Steering Committee

| Name | Sponsor |
|---|---|
| Andreas Hölker | Addax Petroleum Services |
| Heron Antônio Schots | Centro Potiguar de Geocîencias |
| Thomas Hertweck | Fugro Seismic Imaging |
| Paul Krajewski | Gaz de France |
| Dan Grygier | Landmark Graphics Corporation |
| Jan Erik Lie | Lundin |
| Gerd Rybarczyk | Petrologic Geophysical Services |
| Rune Øverås, Jon Sandvik | PSS-Geo |
| Bertrand Duquet | Total E&P RD |
| Henning Trappe | TEEC |

## COMPUTING FACILITIES

The Hamburg group has access to a 264 nodes (16 dual core CPUs, 8448 cores in total) IBM p575 "Power6" cluster at the German Computer Center for Climate Research (Deutsches Klimarechenzentrum, DKRZ) for numerically intensive calculations. It is equipped with 20 TeraByte of memory and its performance per core is 18.8 GigaFlops. There is also access to a IBM Linux cluster with 256 nodes (2 quad core Opteron, 32 GB each). A SUN Fire X4600 (8 dual core Opteron, 32 GB) is exclusively available for the group's computing demands. Additional computer facilities consist of several Linux workstations and Linux PCs. Furthermore, the group has exclusive access to a Maxeler MaxWorkstation with a 24 GB memory MAX3 acceleration card which is FPGA based.

The research activities of the Campinas Group are carried out in the Computational Geophysics Laboratory. The Lab has 15 Linux PC workstations connected by a dedicated jhigh-speed network, suitable for parallel processing. Educational grants provide seismic packages from leading companies such as Landmark and Paradigm. Besides State Government funds, substantial support both for equipment and also scholarships are provided by the Brazilian Oil Company Petrobras. An extension of the Lab with substantial increase of computer power and space in the new facilities of the Center of Petroleum Studies went fully operational in 2012. The new Lab extension counts on another 30 Linux PC workstations that rely on resources shared by a high-performance server and provide access to a 3Tflops cluster with 2TB RAM. The LGC also has remote access to the computing facilities of the Petrobras Research Center in Rio de Janeiro.

The local facilities of the WIT group in Karlsruhe mainly consist in about 30 clustered quad-core Linux workstations. For large-scale computational tasks, a Hewlett-Packard XC3000 (HC3) Linux cluster and is available on campus. It hosts about 300 nodes with two quad cores each. The total nominal peak performance is 27 Teraflops, the total main memory 10 Terabyte. About 300 Terabyte disk space are available via a Lustre file system and an InfiniBand interconnect. Sharing the same file system, the WIT group in Karlsruhe co-funded and has exclusive access to the SCC Institutscluster 2 (IC2) which is a distributed memory parallel computer with 400 16-way compute nodes where each node has two Intel Xeon Octa-Core sockets with Sandy Bridge architecture, 2.6 GHz frequency and 64 GB local memory. The total nominal peak performance is 132 Teraflops, the total main memory 28.3 Terabyte. In addition, the WIT group in Karlsruhe has access to the computing facilities of the state-owned bwGRiD consisting of a total of 101 IBM blades centers distributed over seven universities in Baden-Württemberg. Furthermore, successful project proposals at the Jülich Supercomputing Centre (JSC) and the High Performance Computing Center Stuttgart (HLRS) has granted access and a large volume of computing hours for the Juropa Clustercomputer and the Cray Hermit Supercomputer. The Juropa super computer consists of 8640 cores total, 52 Terabyte main memory with a peak performance of 101 TeraïňĆops, while the Hermit cluster computer consists of 3552 cores total, about 150 Terabyte main memory and with a peak performance of 1.045 Petaflops. Both super computers will be used for large scale forward simulation and full waveform tomographies.

The main computing facility at the Geophysics Graduation Program in Belém is the Seismic Processing Lab (ProSis) . The hardware resources include: several networked Linux-PCs and for large-scale applications, a cluster of PCs with 15 dual-processor nodes with Tesla GPGPU cards in 8 nodes. The proprietary software packages available for seismic applications are ProMAX and MATLAB.

# WIT research personnel

**Ivan Abakumov** is a Master student in St. Petersburg State University. His research interests are time imaging, converted waves, time-lapse seismic, geophysical data processing and computer programming. Ivan is a student member of EAGE, SGE and SPE.

**Khawar Ashfaq Ahmed** received a B.Sc. from the University of the Punjab in Lahore, Pakistan, in 2005. He received a M.Sc. in Geophysics in 2007 and a M.Phil. in Geophysics in 2009, both from the Quaid-i-Azam University in Islamabad, Pakistan, where he also worked for three years as teaching and research associate in the Department of Earth Sciences. Since 2010, he is enrolled at the University of Hamburg as a Ph.D. student in Geophysics. His current research interests are 3D seismic imaging, CRS stacking, and NIP wave tomography.

**Denis Anikiev** received his MSc in geophysics in 2011 from Saint Petersburg State University, Russia, with a thesis "Methods of dynamic inverse problem for horizontally homogeneous media". He participated in an exchange program with Hamburg University in 2006-2009 during his work on the BSc thesis "Localization of Seismic Events by Diffraction Stacking". Since 2011 he is a Ph.D. student at Earth Physics Department in Saint Petersburg State University. The preliminary title of his Ph.D. thesis is 'Reverse-time migration in isotropic elastic media'. His present research interests include elastic reverse-time migration, full waveform inversion, localization of seismic events, localization of microtremors, dynamic inverse problems for acoustic layered media. He is a student member of SEG, EAGE, SPE.

**Alexander Bauer** received a B.Sc. in Geophysics from Hamburg University in 2012 and is currently M.Sc. student in the Hamburg WIT group. His research interests focus on multiparameter stacking and converted waves.

**Parsa Bakhtiari Rad** received a B.Sc. in Mine Exploration Engineering from the Islamic Azad University, Iran, in 2005. He received a M.Sc. in Exploration Seismology in 2008,from the same university, with a thesis "Application of Karhunen-Loeve Filter in Multiple Attenuation Camparison with Radon Transform on Seismic Reflection Data". He also worked for almost three years as a Data Analyst in 2D/3D seismic data processing center of OEOC-CGGVeritas companies in Tehran and also as a geophysicist in data acquisition fields for geophysical section of National Iranian Oil Company(NIOC). Since 2012, he is enrolled at the University of Hamburg as a Ph.D. student in Geophysics. His current research interests are Diffraction Processing and Imaging, i-CRS.

**Mehrnoosh Behzadi** has received her M.Sc. in seismology from Islamic Azad University of Iran in 2009. Since 2011, she is a Ph.D. student in the Hamburg WIT group. Her research interests include passive seismics, site effects, and exploration seismology.

**Ricardo Biloti** received his B.Sc.(1995), M.Sc. (1998) as well as Ph.D. (2001) in Applied Mathematics from the State University of Campinas (UNICAMP), Brazil. He worked at Federal University of Paraná (UFPR), Brazil, as an Adjoint Professor, at the Department of Mathematics, from May 2002 to September 2005, when he joined Unicamp as an Assistant Professor. He has been a collaborator of the Campinas Group since his Ph.D. 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 (Brazilian Society of Applied Mathematics), SIAM and SEG.

**Rodrigo Bloot** received his M.Sc. (2008) in Applied Mathematics from Federal University of Paraná (UFPR) and his PhD (2012), also in Applied Mathematics, from University of Campinas (UNICAMP), Brazil. In 2011, he joined the Federal University of Latinamerican Integration (UNILA) in Foz do Iguaçu as an Assistent Professor for Applied Mathematics. His research interests include wave propagation and wave equations, and seismic inversion methods.

**Martina Bobsin** is a M.Sc. student in the Hamburg WIT group. Her research interests focus on multiparameter stacking operators.

**Thomas Bohlen** received a Diploma of Geophysics (1994) and a Ph.D. (1998) from the University of Kiel, Germany. From 2006 to 2009 he has been Professor of Geophysics at the Institute of Geophysics at the Technical University Freiberg where he has been the head of the seismics and seismology working groups. Since 2009, he is Professor of Geophysics at the Geophysical Institute of the Karlsruhe Institute of Technology. He is the head of the applied geophysics group. His research interests and experience include: seismic modelling, full waveform inversion, surface wave inversion and tomography, reflection seismic imaging. He is a member of SEG, EAGE, AGU, ASA, and DGG (member of the executive board).

**Pedro Chira Oliva**, received his diploma in Geological Engineering (UNI-Peru/1996). He received his MSc., in 1997 and PhD., in 2003, both in Geophysics, from Federal University of Pará (UFPA/Brazil). He took part of the scientific research project "3D Zero-Offset Common-Reflection-Surface (CRS) stacking" (2000-2002) sponsored by Oil Company ENI (AGIP Division - Italy) and the University of Karlsruhe (Germany). Currently he is full Professor at the Institute of Coastal Studies (IECOS) of UFPA. His research interests include seismic stacking and seismic modeling. He is member of GOCAD consortium (France) and SBGf.

**Tiago A. Coimbra** received a B.Sc. (2007) in Mathematics from Federal University of Espirito Santo (UFES) and an M.Sc. (2010) in Applied Mathematics from University of Campinas (UNICAMP), Brazil. Since 2010 he has been a Ph.D. student in Applied Mathematics at UNICAMP. His research interests include seismic modeling, particularly ray theory, velocity analysis, offset continuation, and image-wave theory. He is a member of SEG and SBGf.

**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 he 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.

**Sergius Dell** received a diploma in Physics from the University of Yekaterinburg (Russia) in 1997. He received his diploma in Geophysics in 2009 from the University of Hamburg. Since 2009 he has been a Ph.D. student at the University of Hamburg. His research interests include CSP data mapping and time migration velocity analysis on CSP gathers, CRS imaging of the time-migrated reflections and velocity model building by Image Incident Point Tomography, extraction of diffraction events using the CRS stack and poststack time migration velocity analysis. In 2012, he successfully defended his Ph.D. on these topics. Since September 2012 he has been working as research geophysicist for Fugro SI.

**Jesper Sören Dramsch** participated in the junior studies programme at the University of Hamburg in 2006. He continued his studies in Geophysics at the same university and finished his BSc thesis in 2010. Recently he is participating in the M.Sc. programme in Geophysics at the University of Hamburg. He is currently working on partial CRS stacks and trace interpolation.

**Simone Dunkl** received her diploma in geophysics at the Karlsruhe Institute of Technology (KIT) in 2010. Afterwards she started her PhD in Karlsruhe, working on 3D elastic full waveform inversion. She is involved in the project âĂđTOolbox for Applied Seismic Tomography (TOAST)âĂIJ funded by BMBF. This project aims to combine different forward modeling and inversion methods in order to develop an efficient and flexible toolbox.

**Norman Ettrich** received his diploma in geophysics in 1993 from the Technical University of Clausthal-Zellerfeld, and a Ph.D. in geophysics (1997) from the University of Hamburg. In 1998-2002, he worked at the research center of Statoil, Trondheim. In 2002, he joined the Fraunhofer Institut für Techno- und Wirtschaftsmathematik in Kaiserslautern, Germany. Since 2005, he has been contributing to building up research activities in the fields of seismic migration, processing and visualisation. His key interests are seismic migration, seismic processing, ray tracing, and anisotropy. He is a member of EAGE and SEG.

**Yaqueline Figueredo** graduated as Engineer Cadastral and Geodest in 1997 from Distrital University of Colombia, she received a M.Sc. in Geophysics in 2003 from the National University of Colombia, she worked for three years teaching Geophysics and Physics, and she also worked on seismic imaging and seismic attenuation for five years in the Geophysical Group of the Colombian Petroleum Institut being part of the Tenerife Multicomponent project and complex areas in the Piedemonte Llanero project. Since 2011, she is enrolled at the University of Hamburg as a PhD student in Geophysics. Her current research interest is seismic imaging.

**José Jadsom de Figueiredo** received a B.Sc. (2006) in Physics from Federal University of Paraiba (UFPB), an M.Sc. (2008) in Physics, and a PhD (2012) in Petroleum Science and Engineering from the State University of Campinas (UNICAMP), Brazil. During his PhD, he spent one year (2010-2011) at Allied Geophysical Laboratories at Houston University. In October 2012, he has joined the Faculty of Geophysics at Federal University of Pará (UFPA) as an Associate Professor. His research interests include seismic imaging methods, particularly diffraction imaging, physical modeling of seismic phenomena, anisotropy and rock physics . He is a member of EAGE, SEG, SBGf and SPE.

**Dirk Gajewski** holds the chair of Applied Seismics at the University of Hamburg. Until 2006 he worked at the same institution as associate professor. He received a diploma in geophysics in 1981 from Clausthal Technical University and a Ph.D from Karlsruhe University in 1987. After his Ph.D, 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 asymptotic, seismic modeling, and processing of seismic data from isotropic and anisotropic media. Together with Ivan Psencík, he developed the ANRAY program package. He is a member of AGU, DGG, EAGE, and SEG, and served as Associate Editor for Geophysical Prospecting (section anisotropy). Since 2009 he is a member of the research committee of the EAGE. Besides his activities in WIT he is vice director of the Centre for Marine and Climate Research.

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**Andre Kurzmann** studied geophysics at the TU Bergakademie Freiberg. In 2006 he received his diploma in geophysics. From 2006 to 2007 he worked in several engineering offices. His tasks were supervision, performance and analysis of geophysical measurements. From 2007 he is has been a Ph.D. student at the Institute of Geophysics, TU Bergakademie Freiberg (2007-2009) and at the Geophysical Institute, Karlsruhe Institute of Technology (2009-2012). In 2012 he received a doctorate in natural sciences from the Faculty of Physics, with a thesis on the applications of 2D and 3D full waveform tomography in acoustic and viscoacoustic complex media. His research interests focus on 2D seismic modelling of acoustic/elastic wavefields and 2D and 3D full waveform inversion applied to reflection and crosshole acquisition geometries. He is a member of EAGE.

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**Niklas Thiel** received his Bachelor of Science in Geophysics at the Karlsruhe Institute of Technology (KIT) in 2011. His topic was the processing of a marine 2D reflection seismic profile. Afterwards he started with the Master program in Geophysics and is now working on his Master thesis. His research interests focus on 2D acoustic full waveform inversion (FWI) particularly with regards to the problem of detecting sub-salt structures. He is member of the DGG (member of the executive board) and student representative of the German Geophysics students.

**Martin Tygel** received his B.Sc. in physics from Rio de Janeiro State University in 1969, his M.Sc. in 1976 and Ph.D. in 1979 from Stanford University, both in Mathematics. He was a visiting professor at the Federal University of Bahia (PPPG/UFBa), Brazil, from 1981 to 1983 and at the Geophysical Institute of Karlsruhe University, Germany, in 1990. In 1984, he joined Campinas State University (UNICAMP) as an associate professor and since 1992 as a full professor in Applied Mathematics. Professor Tygel has been an Alexander von Humboldt fellow from 1985 to 1987. In that period, he conducted research at the German Geological Survey (BGR) in Hannover. From 1995 to 1999, he was the president of the Brazilian Society of Applied Mathematics (SBMAC). In 2002, he received EAGE's Conrad Schlumberger Award, and in 2007 the Lifetime Achievement Award by the Brazilian Geophysical Society (SBGf). Prof. Tygel's research interests are in seismic processing, imaging and inversion. Emphasis is aimed on methods and algorithms that have a sound wave-theoretical basis and also find significant practical application. These include, for example, the unified approach of seismic reflection imaging (problem-specific combinations of true-amplitude migration and demigration) and, more recently, data-driven seismic imaging approaches such as the Common Reflection Surface (CRS) method. Prof. Tygel is a member of SEG, EAGE, SBGf, and SBMAC.

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