Wave Inversion Technology Consortium

Wave Inversion Technology
established 1996 in Karlsruhe, Germany

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Universität Hamburg
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Preface

In 2016, WIT is in its 20th year. This would be a good reason to celebrate. However, nobody, neither WIT researchers and students nor the exploration community as a whole are in party mode right now. We were all familiar with the usual ups and downs in the exploration business but the current crisis has reached an extent that has not been experienced by the exploration community for many decades. The next boom is going to come but the predictions as to when this crisis may end differ substantially and the assumptions rely not just on business but also on politics.

World-wide, far more than 200.000 people were laid off and current students are getting more and more concerned about their future. These concerns apply particularly to the graduates who just finished, whereas the students graduating in two to three years may already face a totally different situation. The end of the oil price crisis will be followed by a talent crisis since many people who were laid off have meanwhile left the exploration business. This gap needs to be filled and will provide new opportunities.

This report compiles the highlights of the WIT research in 2015. The research output of WIT was not yet affected by the crisis and the report is as strong as in the previous 19 years. It contains 20 papers that cover the whole bandwidth of the WIT portfolio, ranging from contributions to imaging and modeling to full waveform methods and complemented by manuscripts on passive seismics and other topics. Many of these reports were developed by students, which we could not have employed without your continuing support.

In addition to providing exciting results, some of our students have successfully defended their Ph.D. degrees in 2015. We congratulate Drs. Mehrnoosh Behzadi, Khawar Ashfaq Ahmed, and Benjamin Schwarz. You will find some of their work not only in the report, but also on the accompanying CDROM and the WIT website.

As in previous years, WIT researchers have not only attended and presented their work at national and international conferences like the EAGE and SEG annual meetings and the workshop meeting on “Active and Passive Seismics in Laterally Inhomogeneous Media” (APSLIM) in the Czech Republic. WIT researchers have also co-organized two workshops held during the EAGE annual meeting, where the workshop on “Full Waveform Inversion for Near-Surface Characterization” was organized by Jan van der Kruk and Thomas Bohlen while Kees Wapenaar, Stefan Buske, and Dirk Gajewski served as conveners of the workshop on “Seismic Imaging – Latest Developments.”

All this would not have been possible without the continuing support of our sponsors for which we once again thank you on behalf of all WIT teams, researchers, and students.

Hamburg, 2016/15/02, Dirk Gajewski

Summary: WIT report 2015

IMAGING

Bakhtiari Rad et al. propose a 3D data-driven workflow for time-imaging based on an extension of the CRS-based prestack diffraction separation method. The workflow exploits the fact that stacking velocities for diffractions do not depend on reflector dip. Therefore, stacking velocities obtained from diffraction-only data can be directly used for time migration without further need for residual move-out correction. The proposed method combines the weighting function with the partial CRS stacking technique to separate diffractions before stacking. Subsequently, automatic picking is applied to diffraction velocity spectra to determine a time migration velocity model. Application to a complex 3D synthetic data set confirms the potential for diffraction separation as well as time migration velocity model building using diffractions.

Bauer et al. apply an enhanced version of the previously introduced diffraction traveltime decomposition approach to simple and complex data and show that the method is able to enhance diffractions in the prestack domain even at large offsets entirely based on zero-offset information.

Bauer et al. revisit the zero-offset-based NIP tomography as a tool to efficiently invert for the subsurface velocity structure. In contrast to previous investigations, they focus on non-Snell scattering contributions of the wavefield and show, by exploiting their high ray-path redundancy and illumination properties, that diffractions bear the potential of inverting systematically higher-resolved models than reflection-only data.

Borin et al. discuss computational performance on processing methods that heavily rely on the evaluation of traveltime and the semblance functions. The use of OpenCL is investigated to accelerate these computations on multicore CPUs, GPUs, and other hardware accelerators. Experiments indicate that the OpenCL code is highly portable among different computing devices. The performance results suggests that GPUs are promising computing devices to accelerate seismic processing methods that rely on semblance computations.

Coimbra et al. discuss a multi-path approach to improving the conflicting-dip problem in multi-parameter stacking techniques and demonstrate its functionality by means of numerical examples with the offset-continuation trajectory (OCT) stack.

Glöckner et al. investigate the possible application of the implicit CRS approach as kinematic time demigration operator. The method is applied to synthetic and field data and shows the feasibility of the approach.

Salcedo et al. optimise the parameters of complex-Padé Fourier finite-difference migrations in order to extend the range of imageable reflector dips. They show that with optimised parameters, a one-term Padé expansion is sufficient to image dips up to 65 degrees. The second term only leads to improvements for small ratios between the reference and model velocities.

Santos et al. present a workflow for the construction of initial velocity-models for full-waveform tomography (FWT) methods consisting of automatic time-migration velocity analysis by means of double multi-stack migration, followed by time-to-depth conversion by image-ray wavefront propagation. Evaluation of the converted velocity model as an initial velocity model in an acoustic FWT process indicates the potential to achieve a fully automatic tool for initial-model building in a FWT workflow.

Walda and Gajewski improve the common-reflection-surface (CRS) stack by incorporation of conflicting dips in combination with a global optimization scheme. First the quality of the estimated attributes is demonstrated. Afterwards the method is applied to partial CRS to regularize and enhance prestack data. To correctly estimate the CRS operator, we use differential evolution where we divide the angle space in several intervals to account for conflicting dips. Previously masked events are now visible as demonstrated by diffraction separation.

Xie and Gajewski introduce the particle swarm optimization (PSO) algorithm to simultaneously search the initial 3D CRS attributes, which is a desired search strategy compared to pragmatic three-step grid search.

Yang et al. suggest a partial time demigration method for enhancing prestack data quality. It is based on a single square root equation in terms of midpoint displacement, half-offset and migration velocity. By applying partial time migration followed by the new partial time demigration, the quality of original data can be improved. The newly-generated prestack data can then be used as input for conventional processing and thus result in better images. Application to a simple and a complex synthetic data set as well as to field data confirms that the signal-to-noise (S/N) ratio of the resulting prestack data is improved. Furthermore, the method can be utilised for prestack data regularisation.

MODELING

Bohlen and Wittkamp investigate the implementation of the staggered Adams-Bashforth method (ABS) to increase the temporal accuracy in FDTD seismic modelling. ABS is a multi-step method that uses previously calculated wavefields to increase the order of accuracy in time. In 1-D and 3-D simulation experiments they verify the convincing improvements of simulation accuracy of the fourth-order ABS method. In a realistic elastic 3-D scenario the computing time reduces by a factor of approximately 2.4, whereas the memory requirements increase by approximately a factor of 2.2. The ABS method thus provides an alternative strategy to increase the simulation accuracy in time by investing computer memory instead of computing time.

Schleicher and Costa derive a separable strong-anisotropy approximation for the dispersion relation of pure qP waves in VTI media. A comparison to results from a low-rank implementation of the full dispersion relation demonstrates that this can provide high-accuracy wavefields even in strongly anisotropic inhomogeneous media.

FULL WAVEFORM INVERSION

Kazei and Tessmer introduce a novel regularization algorithm for full-waveform inversion via non-stationary filtering of the misfit functional gradients. The non-stationary filtering is usually computationally intensive, yet the proposed algorithm is very efficient since it requires neither the computation of non-stationary convolutions, nor the model space extension. The filter was tested on the Marmousi model and proved to be helpful to improve FWI convergence.

Kunert et al. apply acoustic full waveform inversion to a marine seismic data set acquired in shallow water. A complex inversion workflow is developed and a satisfactory model of P-wave velocity is recovered from OBC data. Small-scale structures, such as fault zones, were reconstructed. Due to low velocities, we assume gas accumulations in these areas.

OTHER TOPICS

Coimbra et al. propose a noise-reduction algorithm that is applied to a CRS stacked volume. By means of the proposed algorithm, each sample in the CRS stacked volume will be spread out to its neighboring points in the volume along the CRS diffraction traveltime surface that pertains to that sample. The proposed method was applied to synthetic (Sigsbee2b-nfs) and real (Jequitinhonha) datasets with promising results in terms of better signal-to-noise ratio, event enhancement and conflicting-dip corrections.

Coimbra et al. review and advance time-to-depth conversion by means of so-called modeling rays. This approach avoids the construction of image rays, thus avoiding its disadvantages, which include problems of caustics,interpolation and regularization that are characteristic of image ray-tracing techniques. Besides a review of the concept and tracing of modeling rays, we propose a new algorithm for time-to-depth conversion that is simpler and more efficient than the ones available in the literature. Applications to synthetic and real data provide encouraging results.

Faccipieri et al. proposes an iterative process for CRS processing which consists of the following steps: (a) User-selection at a few (picked) points, on an initial (given) CMP stacked section and global exhaustive evaluation of CRS parameters on these points; (b) Interpolation/extrapolation of the obtained CRS parameters to fill out all sample positions that comprise the ZO section or volume to be constructed; (c) Global refinement of CRS parameters using the previously obtained parameter as initial values; (d) Computation of the CRS stack with the refined parameters and finally (e) This process is repeated by adding, subtracting or editing points until a desired result is achieved.

Kamioka et al. introduce Minimum Semblance, a simple modification of conventional semblance. It uses the minimum value of several semblance values within a given time window. Numerical examples show that Minimum Semblance increases resolution of semblance sections with comparable computational cost to the conventional measurement.

Maciel and Biloti show a new way to construct a set of descriptors for diffraction operators in order to classify scatterers in seismic sections. This is done using statistical attributes from the distribution of amplitudes along a diffraction traveltime path. The approch brings new light into diffraction imaging and Kirchhoff summation. Results show that automatic classification of scatterers might be performed with classic Machine Learning techniques.

Schwarz et al. introduce a data-driven scheme to simultaneously invert for the spatial location of a passive seismic source and the velocities of the traversed medium. Being based on the attributes of the normal-incidence-point (NIP) wave, the method utilizes two different parameterizations of a geometrically derived stacking operator to estimate the unknown passive source excitation time. Concluding this work, the applicability of the approach is demonstrated with a simple synthetic example.

Vefagh et al. introduce an approach for multiple attenuation, which is applicable to any type of multiple reflection including internal multiples. It includes picking zero-offset traveltimes of multiples in a stacked section which is guided by the coherence, these traveltimes are then used to predict the pre-stack multiples with the help of the stacking velocity. This method performs stable for far offsets and it does not require high computational effort. Both synthetic and field data examples illustrate the potential of the method.

The Wave Inversion Technology (WIT) Consortium

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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 2007, NORSAR joined WIT as research affiliate, and in 2010, Fraunhofer ITWM joined WIT, also 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.

- global (ZO CRS) vs. local (CO CRS) approximations
- estimation of CO CRS attributes from ZO attributes
- amplitude-friendly CRS processing
- improved conflicting dip processing
- 3-D i-CRS operator
- wavefield decomposition using stacking attributes (multiples, reflections, diffractions)
- utilizing super resolution
- pre-stack diffraction/reflection separation
- 5-D CRS and i-CRS interpolation and pre-stack data enhancement
- improved coherence measures (MUSIC, cross-correlation, analytical trace, etc.)
- optimization of multi-dimensional coherence analysis
- data driven isotropic and anisotropic time migration
- wavefield decomposition and filtering in the CSP domain
- inverse CSP mapping
- CRS and diffraction processing of 3-D hard rock data
- angle domain migration
- beam 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
- diffraction stereotomography
- passive seismic data velocity model update
- CRS based time to depth conversion
- tomographic inversion of stacking attributes

Full Waveform Inversion

Research on Full Waveform Inversion (FWI) is moving toward applications to marine reflection seismic data and near surface seismic data (surface waves) and three-component Vibroseis data acquired in crystalline rocks.

- development of robust preprocessing of seismic data for FWI
- multi-parameter FWI
- source wavelet inversion
- accurate methods for geometrical spreading correction
- implementation of 3-D acoustic/elastic/viscoelastic FWI on HPC machines
- FWI in viscoelastic media
- optimization of Finite-Difference forward solvers used in FWI with respect to MPI communication, higher order time integration, variable spatial discretization and smooth free surface topography
- application of pseudo spectral methods in FWI

Modeling and RTM

In modeling and RTM we use FD, FE, 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)
- finite element (FE) elastic wavefield modeling
- 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 time domain 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
Tina Kaschwich	NORSAR
Jörg Schleicher	Campinas
Martin Tygel	Campinas
Claudia Vanelle	Hamburg

External Steering Committee

Name	Sponsor
Mikhail Baykulov	Addax Petroleum Services
Thomas Hertweck	CGG Seismic Imaging (UK)
Carlo Tomas	Eni
Paul Krajewski	Gaz de France SUEZ
Shinichi Itoh	Hanshin Consultants
Dan Grygier	Landmark Graphics Corporation
Jan Erik Lie	Lundin
Rune Øverås, Jon Sandvik	PSS-Geo
Henning Trappe	TEEC

COMPUTING FACILITIES

The Hamburg group has access to a 1.500 nodes (two 12-core CPUs, 36.000 cores in total) bullx B700 DLC sytem at the German Computer Center for Climate Research (Deutsches Klimarechenzentrum, DKRZ) for numerically intensive calculations. It is equipped with 120 TeraByte of memory and its peak performance is 1.4 PetaFlops. For medium sized problems there are an IBM Xeon-based 64 cores login node with 512 MB memory and four compute nodes for batch processing accessible. Also 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.

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 high-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 computing facilities of the WIT group in Karlsruhe consist of several local and external clusters, Linux workstations and Linux PCs. For large-scale computational tasks, the Hewlett-Packard XC3000 (HC3) Linux cluster (about 360 nodes, each with two Quadcores, 30 TFlops in total, 11 TeraByte memory) is available on the campus. 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) with 480 nodes, each consisting of 16 cores. The performance is 135.5 TFlops and 28 TeraByte of memory are available. The group has also access to the most powerful cluster at the KIT, the ForHLR (522 nodes, each with 20 cores, 216 TFlops in total and 41 TB memory), funded by the state of Baden-Wuerttemberg and the German research foundation (DFS). Furthermore, successful project proposals at the JÃijlich Supercomputing Centre (JSC) has granted access to a large volume of computing hours for one of the newest and best supercomputers in Europe, the JURECA Clustercomputer. This supercomputer consists of 1872 nodes, each with 24 cores with a theoretical computational power of 1.8 PetaFlops. In 2015 the WIT group in Karlsruhe also acquired the new SGI UV20. With its 96 cores and 512 GB shared memory it is ideal for small test computations and code development. The cluster is already used extensively by our Master and PhD students.

Fraunhofer ITWM builds up new compute clusters early 2014. The largest machine consists of 192 dual Intel Xeon E5-2670 ("Sandy Bridge") (i.e. 16 CPU cores per node) with 64 GB RAMeach, 300 GB HDD, 2x Gigabit Ethernet and FDR Infiniband interconnect. In total, 3072 CPU cores, 12 TB main memory, and 57 TB disk space. Estimated peak performance is 56 TFlops. In addition, 4 quad Intel Xeon E5-4650L ("Sandy Bridge") (i.e. 32 CPU cores per node) with 256 GB RAM, 2x 500 GB HDD will be available. The storage system consists of 12 storage servers, connected via FDR Infiniband an 10 Gigabit Ethernet with a total capacity of 200 TB via the Fraunhofer file system. In addition, the HPC department of ITWM runs a cluster with 92 compute nodes, among them 60 Intel Xeon E5-2680 IvyBridge nodes. Disk capacity will be 270 TBytes.

WIT research personnel

Ivan Abakumov received his MSc from St. Petersburg University in 2013. He is now a PhD student in the University of Hamburg. His research interests are time imaging, converted waves, time-lapse seismic, full waveform inversion, geophysical data processing and computer programming. Ivan is a student member of EAGE, SGE and SPE.

Niklas Ahlrichs is a M.Sc. student in geophysics at the University of Hamburg. His research interests focus on conflicting dips, diffractions and CRS.

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 was enrolled at the University of Hamburg as a Ph.D. student in Geophysics, where he performed research on 3D seismic processing with a hybrid approach and diffraction mapping, as well as seismic imaging in a crystalline environment. He successfully defended his Ph.D. in 2015.

Nikolaos Athanasopoulos, M.Sc. (IDEA LEAGUE Joint Master in Applied Geophysics, 2015), started his Ph.D. studies at the Karlsruhe Institute of Technology (KIT) in 2015. He is working in the field of Full Waveform Inversion (FWI). His research focus is the elastic FWI of shallow seismic surface waves and its application in field data. He is member of the EAGE.

Parsa Bakhtiari Rad received a B.Sc. in Mine Exploration Engineering from the Islamic Azad University, Iran, in 2005 and received a M.Sc. in Exploration Seismology in 2008 from the same university with a thesis title "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-CGG companies in Tehran and as a geophysicist in data acquisition fields for geophysical section of National Iranian Oil Company(NIOC) as well. In 2012, he enrolled at the University of Hamburg as a Ph.D. student in Geophysics. His main research interest is processing and imaging of seismic diffractions.

Alexander Bauer received an M.Sc. in Geophysics from Hamburg University in 2014 and is currently a PhD student in the Hamburg WIT group. His research interests focus on imaging and processing of seismic diffractions.

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.

Martina Bobsin married in 2015 and changed her name to Martina Glöckner.

Thomas Bohlen received a Diploma of Geophysics (1994) and a Ph.D. (1998) from the University of Kiel, Germany. From 2006 to 2009 he was Professor of Geophysics at the Institute of Geophysics at the Technical University Freiberg where he was the head of the seismics and seismology working groups. Since 2009, he has been 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, and DGG.

Simone Butzer received her diploma in geophysics at the Karlsruhe Institute of Technology (KIT) in 2010. Afterwards she started her PhD in Karlsruhe, working on a thesis on 3D elastic full waveform inversion, which she successfully defended in January 2015.

Alexandre William Camargo received his BS (2011) in Applied Mathematics from the State University of Campinas (UNICAMP), Brazil. He is currently about to finish the Master Science in Applied Mathematics in the same university. His professional interests include seismic modeling and numerical methods for differential equations. He is member of SEG (Society of Exploration Geophysicists).

Tiago A. Coimbra received a B.Sc. (2007) in Mathematics from Federal University of Espirito Santo (UFES), M.Sc. (2010) and Ph.D. (2014) in Applied Mathematics from University of Campinas (UNICAMP), Brazil. He is now a researcher at the Center for Petroleum Studies (CEPETRO) 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, EAGE 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.

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.

Jorge H. Faccipieri received a B.Sc. (2010) in Physics from University of Campinas (UNICAMP) and a M.Sc. (2012) in Petroleum Science and Engineering at the same University. He is now a researcher at the Center for Petroleum Studies (CEPETRO) and also a Ph.D. student in Petroleum Science and Engineering, both at UNICAMP. His research interests include multiparametric traveltimes, velocity analysis and diffractions. Jorge is a student member of EAGE and SBGf.

Mario Rubén Fernandez received his M.Sc. at the Institut de Physique du Globe de Paris and started his Ph.D studies at the Karlsruhe Institute of Technologies (KIT) in 2015. He is working for the CRC 1173 Ẅave phenomenaön the implementation of full waveform inversion of seismic wave attenuation.

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.

Laura Gaßner studied geophysics at the Karlsruhe Institute of Technology (KIT) and received a B.Sc in 2011 and a M.Sc degree in 2014. She is now a Ph.D. student at the Geophysical Institute of KIT and works on the characterization of gas hydrate deposits with full waveform inversion within the project SUGAR (SUbmarine GAs hydrate Resources).

Håvar Gjøystdal is Research Manager of Seismic Modelling at NORSAR in Kjeller, near Oslo. He also holds an adjunct position of Professor of Geophysics at the Department of Earth Science, University of Bergen. In 1977 he joined NORSAR and started building up research activities within the field of seismic modelling, which to-day include both R&D projects and services and software products for the petroleum industry. Key topics are ray tracing, seismic tomography, and time lapse seismic modelling. He is a member of SEG and OSEG.

Carina Guntern is a M.Sc. student at the University of Hamburg. She received her B.Sc. in geophysics in 2013 with a Bachelor thesis on diffraction imaging with the CRS and i-CRS operator. Her research interests focus on diffraction imaging and multiparameter stacking operators.

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Tina Kaschwich received her diploma in geophysics (2001) and a Ph.D. in geophysics (2006), both from the University of Hamburg. Since 2005 she has been a research fellow at the seismic modelling group at NORSAR, Norway. Her research interests are ray tracing and wavefront construction methods, imaging and illumination studies for survey planning and quality control for different model and wave types. She is a member of EAGE, OSEG and SEG.

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