Wave Inversion Technology Consortium

Campinas
Karlsruhe
Hamburg

Wave Inversion Technology
established 1996 in Karlsruhe, Germany

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Contents

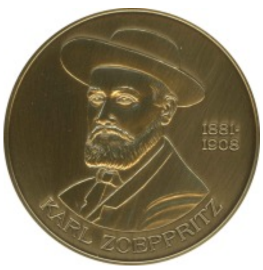
Preface

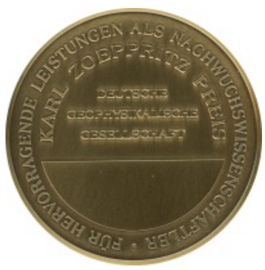
In this 23rd Annual WIT Report, we share with you eleven papers that represent our latest research in Imaging, Full Waveform Inversion, and Other Topics, such as, e.g., Deep Learning. The finalisation of the report fell right into the outbreak of the Corona pandemic in Central Europe and all travel came to a break down. Lots of changes in our daily routines affected our lives including the way we communicate and teach. The summer semester will be an online semester and we all, students and professors alike, have to get used to it. The direct exchange with students is a substantial component in our previous ways to transfer knowledge and to supervise thesis work. Whereas seminars, lectures and exercises do not suffer too much by these changes, the important practical parts of our study programs, i.e., field and lab work, came to a complete stall. Students relying on field and lab work in their theses and programs were facing severe consequences since delays in finishing their programs are very likely. Students, who just finished their studies may face a much more complicated job hunt than prior to the pandemic. Because of the reduced energy demand, uncertainties on the health of the hydrocarbon business may influence the availability of open positions.

What has not changed is our enthusiasm for seismics and science but we have to exercise it differently and we are still learning. Because of the good experience with online meetings and webinars I do expect less travel in the future but I can hardly believe that the annual meetings of the big societies like SEG of EAGE will entirely transfer to virtual for the coming years. For 2020 though, it is most likely the preferred and only way to have a meeting at all but we will miss the personal exchange, networking and interaction which plays such a major role in these conventions. The results presented in this report summarise the 2019 WIT research and thus were obtained by n̈ormalm̈eans. The new n̈ormalïs still under construction.

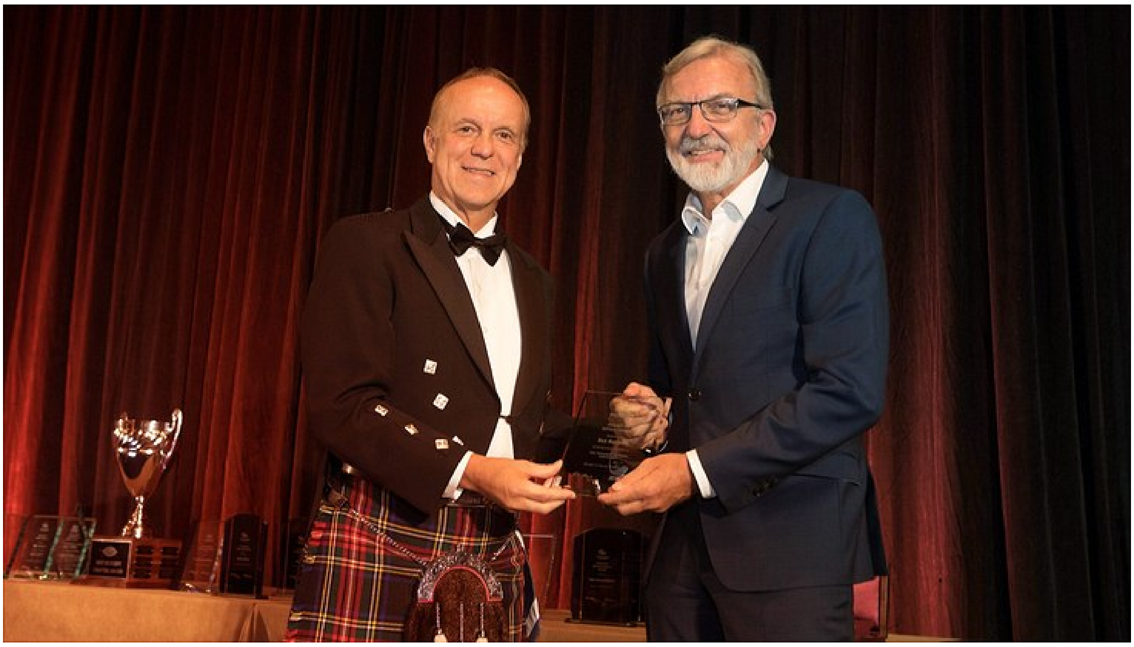
In addition to the papers in this report and contributions to conferences and workshops, we are pleased to announce that five WIT researchers have completed their Ph.D. research. You can find links to the theses by Dr. Alexander Bauer, Dr. Alexandre William Camargo, Dr. Laura Gassner, Dr. Martina Glöckner, and Dr. Pavel Znak on the WIT webpage.

Not only was 2019 a successful year for us in general, but also in particular for WIT alumni Dr. Benjamin Schwarz and WIT director Dr. Dirk Gajewski. Benjamin Schwarz was awarded this year's DGG (Deutsche Geophysikalische Gesellschaft) Zoeppritz Medal. The medal, which recognises outstanding contributions of a young scientist, was presented to Benjamin during the DGG's 79th Annual Meeting.





Furthermore, Dirk Gajewski received an award for his service as 2019 SEG (Society of Exploration Geophysicists) Honorary Lecturer Europe. The topic of his lecture, which he presented in more than twenty locations throughout Europe, was "Wavefront attributes – A tool for processing, imaging, and model building." The award was presented to Dirk during the 89th Annual Meeting of the SEG in San Antonio, Texas, USA by SEG president Robert Stewart.



While WIT researchers have also, just like in any year in the past up until now, presented their results on conferences and workshops, science and communication in particular will undergo, as already discussed, a significant change in the future due to the Sars-Cov2 pandemic.

Despite the uncertain future of the world at large, we will make sure that WIT scientists will continue to perform research on the highest level and follow our mission to provide the most accurate and efficient seismic modelling, imaging, and inversion using elastic and acoustic methods. Your continuous sponsorship is especially appreciated in these times: On behalf of the WIT research teams, researchers, and students, we thank you whole-heartedly for your support.

Hamburg, March 2020
Dirk Gajewski

Summary: WIT report 2019

IMAGING

Albano et al. derive several alternative expressions for the true-amplide imaging conditions in reverse-time migration (RTM). They demonstrate by means of numerical examples using the Marmousi and Sigsbee2A data that the quality of the migrated image strongly depends on the version chosen for implementation. The best results are achieved with a version that combines second derivatives of the source wavefield with the Laplacian operator.

Assis et al. review the background equations of the Joint Migration Inversion (JMI) in their continuous form, evaluate JMI methodology using the multiparameter Gauss–Newton method to estimate simultaneously image and slowness updates, and compare the results to those of the conventionally used steepest-descent method. The results show that their JMI implementation can provide a good depth migrated image and a satisfying initial velocity model for a subsequent Full Waveform Inversion.

Assis and Schleicher propose to take advantage of the structural information available in the image by means of a simple Tikhonov type regularization applied to the tomography part of joint migration inversion (JMI). Tests with two synthetic data sets indicate the effectiveness of the proposed regularization. The methodology developed here is readily applicable to any seismic tomography at practically no additional cost if a migrated image is available.

Bedendo et al. discuss several practical aspects of implementing time migration velocity analysis by double path-integral migration, ranging from the parametrization of the weight function to the stabilization of the division and the selection of only meaningful velocities. By means of tests on a wide range of velocity models, they find a robust implementation of the method.

Machado et al. test and compare three iterative approaches for depth migration velocity analysis (MVA) by image-wave propagation in common-image gathers. The first implementation is a global update, aiming at updating the whole model in each iteration, whereas the second one is a layer-stripping procedure, updating the model one layer at a time, from top to bottom. The third implementation is a mixture of both the first and second approaches. It uses the result of the first iteration from the global update to guide the later iterations of the layer-stripping experiment. The layer-stripping approach provides a much better result than the global update and also provides a better result than the one given by the mixture of both techniques. Since MVA by image continuation in CIGs is a rather inexpensive procedure which starts at no a-priori knowledge of the medium, it can be used to build initial models for more sophisticated inversion techniques.

FULL WAVEFORM INVERSION

Athanasopoulos and Bohlen show through a numerical study the influence of shallow anomalies on the recorded seismic wavefield when surface waves dominate the waveform. Through this study the impact of cross-talk between the elastic parameters is examined and insights are given for the proper application of multiparameter inversion schemes, such as full-waveform inversion.

Gao et al. give a short introduction to multiparameter FWI. Synthetic reconstruction tests allow to investigate the crosstalk between parameters and show that attenuation must be considered during the inversion. Both synthetic and field data cases prove the reliability of multiparameter FWI.

OTHER TOPICS

Bauer et al. introduce a modified implementation of wavefront tomography, which enforces the focusing of diffracted wavefronts in depth, thus allowing to obtain depth velocity models for zero-offset or passive-seismic data without the need for curvature information.

Dell et al. presented an approach for characterizing diffraction attributes. The also showed how to correlate diffraction and reflection attribute using a deep neural network.

Magalhaes et al. compares two iterative schemes for the Marchenko integral equation in one dimension. Both schemes can successfully recover the kinematics, albeit the dynamics can have an incorrect scale depending on the difference between the velocity at the injected source and the focusing point. One scheme is faster than the other but is more susceptible to noises and can retrieve only the full redatumed Green's function while the other is less noisy and separates the Green's function in its one-way components.

Walda, Dell, and Gajewski present an automatic way to extract valuable subsurface information from any kind of migrated data. In one case, thez extract seismic attributes from the migrated data and cluster them using a deep convolutional autoencoder as preconditioner. This leads to an unsupervised interpretation of geometrical features like faults. In the second case they cluster seismic data directly, using a deep convolutional autoencoder as preconditioner again. In this case they train on the time migrated F3 block data from offshore Netherlands and apply the method to the recently opened depth migrated data of the Volve reservoir. The autoencoder preconditioner is fixed, which demonstrates the stability and generalizability of the approach. The clustering identifies an anomaly in the area of the former reservoir.

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.

WIT RESEARCH TOPICS

The WIT consortium has the following main research directions with the goal to establish the most accurate and efficient seismic modeling, imaging, and inversion using elastic and acoustic methods. Since 3 years machine learning techniques are applied in processing, imaging, model building and interpretation. This research topic is very likely to gain more and more weight in the research of the WIT research team. 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

Wavefront attributes as derived from multi-parameter processing and play play a key role in the WIT research and represent the backbone of many research topics.

- deep learning techniques for 5-D interpolation, regularization and de-noising
- interpretation and attribute analyses by unsupervised machine learning
- machine learning in processing, imaging and model building
- event tagging using deterministic and machine learning approach
- estimation of CO wavefield attributes from ZO attributes
- amplitude-friendly multi-parameter processing
- wavefield decomposition using wavefield attributes and adaptive subtraction
- pre-stack diffraction/reflection separation by machine learning
- improved coherence measures (MUSIC, cross-correlation, analytical trace, etc.)
- data-driven isotropic and anisotropic time migration
- construction of Common Reflection Point (CRP) gathers
- beam migration
- image wave re-migration

Velocity Model Building

Many of our model building approaches also exploit wavefront attributes, where the tomographic approach may be applied in the data domain or in the image domain.

- Velocity model building by diffraction/reflection focusing
- passive seismic data velocity model building with wavefront attributes
- wavefront attribute-based time to depth conversion
- focusing approach in wavefront tomography
- uncertainty estimates derived from focusing analysis
- anisotropic wavefront tomography
- focusing tomography of Common Reflection Point gathers
- full waveform inversion (see also below)

Full Waveform Inversion

Research on Full Waveform Inversion (FWI) is moving toward applications on marine and land seismic data and to non destructive material testing. The methodological developments include

- multi-parameter reconstruction of seismic velocities, attenuation and anisotropy
- 3D visco-elastic FWI of multi-component shallow seismic wavefields
- Higher order optimization using quasi Newton and full Newton methods

Modeling and Reverse Time Migration

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

- FE elastic wavefield modeling
- computational optimization of FD and spectral method approaches for acoustic, elastic, and anisotropic media, including benchmarking
- improved one-way wave equations
- reflection impedance description of reflection coefficients
- tuning effects in AVO and AVA

Passive Seismics

Passive seismic moveout is equivalent to moveout of diffraction events, which enables a unified workflow for processing and imaging of active and passive seismic data.

- passive seismic data enhancement and regularization with wavefront attributes
- source time estimation and velocity inversion
- imaging with natural Green's functions
- simultaneous location and velocity model building
- joint wavefront tomography and passive seismic imaging
- source signature extraction
- localization uncertainties from focusing analysis
- real time processing methodology for passive seismic data

WIT STEERING COMMITTEES

Internal Steering Committee

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

External Steering Committee

Name	Sponsor
Dan Grygier	Landmark Graphics Corporation
Henning Trappe	TEEC

WIT research personnel

Bessam Alubeyid received his Bachelor of Petroleum Engineering at Al-Baath University (Syria) in 2012. Subsequently, he worked at Hayan Petroleum Company as process engineer. Currently, he is a student enrolled in the Master's program in Geophysics at KIT, working on his Master's thesis. His thesis deals with 3D simulation of seismic wave propagation in a tunnel model for EPB-tunnel boring machines with processing of synthetic and field data.

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.

Alexander Bauer received his B.Sc. (2012), his M.Sc. (2014) and his Ph.D. (2019) in Geophysics from the University of Hamburg. His research interests focus on analyzing and imaging the diffracted wavefield and exploiting it for depth-velocity-model building. He is a member of DGG, EAGE and SEG.

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.

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.

Oliver Bölt received his B.Sc. in Geophysics/Oceanography in Hamburg in 2020. In his B.Sc. thesis, he investigated the determination of common reflection point trajectories. For his masters programme, he continues his work on this topic.

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 (UNI-

CAMP), 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.

Sergius Dell received his diploma (2009) and a Ph.D. (2012) in geophysics from the University of Hamburg. In 2012-2015, he worked at Fugro and CGG (UK). Since 2016 he has been self-employed. His key interests are least-squares seismic migration, multiple migration, travel-time tomography, diffraction processing, ray tracing, and dual-semblance analysis. He is a member of EAGE and SEG.

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 "Wave phenomena" on 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.

Lingli Gao received her PhD from China University of Geosciences (Wuhan) in 2016. Now she is a Postdoc researcher at Zhejiang University. Currently, she is a visiting scholar at KIT working on high-frequency surface-wave methods.

Laura Gaßner studied Geophysics at Karlsruhe Institute of Technology (KIT) and received a BSc degree in 2011, an MSc degree in 2014, and a PhD in 2018. Throughout 2018 she has worked on the characterization of gas hydrate deposits with full-waveform inversion within the project SUGAR (SUbmarine GAs hydrate Resources).

Martina Glöckner received her Ph.D. in 2019 from the University of Hamburg for her thesis on Advanced Time Imaging. Prior to that, she received her M.Sc. (2014) and B.Sc. (2012) in geophysics at the University of Hamburg, where the main focus of her work was the application of multiparameter stacking operators.

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.

Thomas Hertweck received a diploma in Geophysics (2000) and a doctor's degree of natural sciences (2004) from the University of Karlsruhe, Germany. He joined Fugro in September 2004 as researcher and software developer before becoming an R&D manager in 2007 and global head of R&D in 2011. In 2013 Thomas became an R&D manager for external research at CGG following the successful takeover of Fugro's Geoscience Division. At CGG he was also a member of the business line's R&D management team, the company's technology board, and its IP and HSE committees. After more than 12 years in the UK Thomas returned to Germany in January 2017 when he joined KIT's Geophysical Institute as senior research fellow and teaching assistant. Thomas' research interests include all aspects of seismic acquisition, processing and imaging as well as HPC software development. He serves as reviewer for various journals and is a member of SEG, EAGE, DGG and the Editorial Board of JSE.

Einar Iversen received Cand.scient. (1984) and Dr. philos. (2002) degrees in geophysics, both from the University of Oslo, Norway. He has worked for NORSAR since 1984 and is currently a senior research geophysicist within NORSAR's Seismic Modeling Research Programme. He received the Best Paper Award in Geophysical Prospecting in 1996. His professional interests are seismic ray theory and its application to modeling, imaging, and parameter estimation. He is a member of SEG and EAGE.

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.

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.

Stefan Knispel reveived his BSc in Geophysics/Oceanography in Hamburg in 2017. In his BSc thesis, he investigated the processing of diffractions in the shot gather domain. For his MSc thesis, he is continuing his work on this topic including machine learning methods.

Valérie Krampe received a BSc degree in Geophysics in 2016 and an MSc degree in Geophysics in 2018, both from Karlsruhe Institute of Technology (KIT). Her Master's thesis focused on anisotropic full-waveform inversion.

Daniel Krieger received his BSc degree in Geophysics from Karlsruhe Institute of Technology (KIT) in 2017. He is currently working on his Master's thesis in which he studies the application of 2D elastic full-waveform inversion in areas with topographic variations of the free surface.

Fabian Kühn received a BSc degree in Geophysics in 2016 and an MSc degree in Geophysics in 2018, both from Karlsruhe Institute of Technology (KIT). His Master's thesis focused on the application of full-waveform inversion in the field of medical imaging.

Isabelle Lecomte received an M.S. (1987) in geophysics, an Engineering Geophysics (1988) degree, and a Ph.D. (1991) in geophysics, all from the University of Strasbourg, France. In 1988-1990, she worked as a Ph.D. fellow at IFREMER/University of Strasbourg. In 1991-1992, she was a post-doctoral fellowship at NORSAR, Norway (grant from EU in 1991, and the Research Council of Norway in 1992). Since 1993, she joined NORSAR permanently as a senior research geophysicist in R&D seismic modelling, and is now a principal research geophysicist. Since 2003, she is also a part-time researcher at the International Centre for Geohazards (ICG, Oslo), acting as the theme coordinator for geophysics. She received the EAGE Eötvös award (best paper, Geophysical Prospecting) in 2001. Her main research interests are seismic modelling (finite-differences, ray-tracing, Eikonal solvers, hybrid RT-FD), with applications to seismic reflection, refraction and tomography in oil exploration, and seismic imaging (generalized diffraction tomography) including resolution studies. More recent studies concerned seismic imaging with SAR-type processing, and simulation of PSDM images. She is a member of EAGE, OSEG, and SEG.

Tingting Liu received an MSc degree from Jilin University in China and started her PhD studies at Karlsruhe Institute of Technology (KIT) in 2018. Her research field is full-waveform inversion of shallow-seismic surface waves in poroelastic media.

Daniel Macedo received a B.Sc. (2004) in Physics and an M.Sc. (2010)in Geosciences from University of Campinas (UNICAMP), Brazil. Since 2010 he has been a Ph.D. student in Petroleum Science andEngineering at UNICAMP. His research interests include wave phenomena, seismic imaging and inversion methods, particularly full waveform inversion, and scattering theory. He is a member of SEG, EAGE and SBGf.

Jonas Müller studies Geophysics at Karlsruhe Institute of Technology (KIT) and received a BSc degree in 2018. He is now working on his Master's thesis on full-waveform inversion in the context of non-destructive testing.

Leo Nesemann received his MSc in computational mathematics in 2006 from Brunel University (London) and a PhD in applied mathematics from the University of Hannover in 2010. Since 2011, he is working as a scientist in the HPC department of the Fraunhofer ITWM in Kaiserslautern. His research interests are highly scalable, efficient applications of FEM and FDM for linear acoustic and elastic equations.

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. From 1996 to 2002, she was a professor for Mathematics at the Federal University of São Carlos (UFSCar), Brasil. She has joined Unicamp in April 2002 as an Assistant Professor and since 2009 as an Associate Professor. Her research interests focus on partial differential equations and include seismic forward modeling and imaging. In particular, she works with finite differences to obtain the solution of the acoustic, elastic and image wave equations, as well as with the Born and Kirchhoff approximations. Presently, she also studies image-wave equations. She is a member of SEG, SBGf, SBMAC, and SBM.

Yudi Pan received his Ph.D. in 2016 from China University of Geosciences (Wuhan), China. Now he is a postdoc researcher at Karlsruhe Institute of Technology (KIT). His research interests include elastic-wave full waveform inversion and high-frequency surface-wave imaging methods.

Antonio J. Ortolan Pereira got his bachelor degree in Geophysics and Economy from the University of Sao Paulo, Brazil, during the early nineties. Since 2000, he has been working for Petrobras in Rio de Janeiro. During this period he has worked as a geophysicist in Seismic Processing and Marine Seismic Acquisition. Between 2008 and 2011 he was involved as a Petrobras manager in the largest time lapse (4D) marine survey in the world (more than 3400 square kilometers in highly congested areas in the Campos and Espirito Santo basins, covering several major offshore fields in Brazil). Currently he is on leave from Petrobras to study Seismic Interferometry towards a master's degree at University of Campinas.

Martin Pontius studied Geophysics at Karlsruhe Institute of Technology (KIT) and finished his MSc in 2016 with a thesis on joint acoustic full-waveform and gravity inversion applied to a synthetic salt dome model. During 2018 he has worked on a new implementation of full-waveform inversion software as part of the WAVE project.

Tan Qin received his Master of Natural Science in Geophysics from Tongji University (China) in 2018. Now he is a PhD student at Karlsruhe Institute of Technology (KIT). His research interests include joint full-waveform inversion of ground penetrating radar and seismic data for near-surface applications.

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