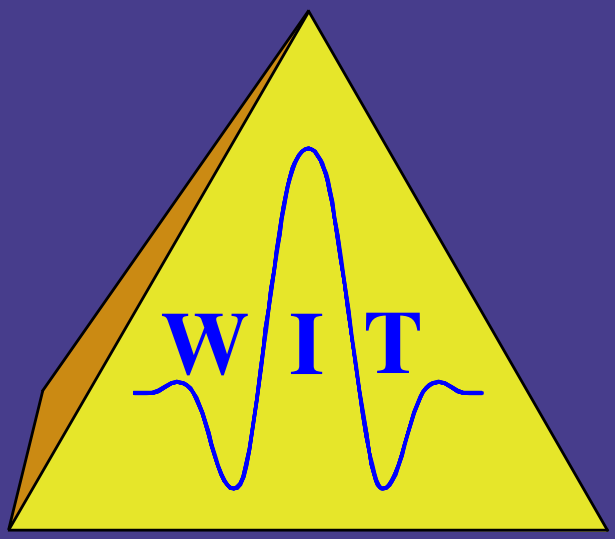
Wave Inversion Technology Consortium



Wave Inversion Technology
established 1997 in Karlsruhe, Germany

Annual Report No. 11
2007

Hamburg, 2008/17/03

Contributions to this WIT report were provided by:

Institute of Geophysics
University of Hamburg
Bundesstraße 55
D-20146 Hamburg
Germany

☎ +49-40-42838-2975
FAX +49-40-42838-5441
✉ dirk.gajewski@zmaw.de

Dept. of Applied Mathematics
IMECC - UNICAMP
C.P. 6065
13081-970 Campinas (SP)
Brazil

☎ +55-19-3788-5984
FAX +55-19-3289-1466
✉ tygel@ime.unicamp.br

Geophysical Institute
University of Karlsruhe
Hertzstraße 16
D-76187 Karlsruhe
Germany

☎ +49-721-608-4443
FAX +49-721-71173
✉ juergen.mann@gpi.uni-karlsruhe.de

Universidade Federal do Pará
Centro de Geociências
Departamento de Geofísica
Caixa Postal 1611
66017-970 Belém (PA)
Brazil

☎ +55-91-3201-7681
FAX +55-91-3201-7693
✉ jesse@ufpa.br

Institute of Geophysics
TU Bergakademie Freiberg
Gustav-Zeuner-Straße 12
D-09596 Freiberg
Germany

☎ +49-3731-392728
FAX +49-3731-392636
✉ tbohlen@geophysik.tu-freiberg.de

WIT web page: http://www.wit-consortium.de/
Email: info@wit-consortium.de

Institute of Geophysics
University of Hamburg

Hamburg, Germany

Contents

Preface

The 11th Annual WIT report marks the end of the transition of the coordination from Karlsruhe to Hamburg. During last year's meeting, Peter Hubral handed the WIT pyramid over to Dirk Gajewski as a symbol. We've been busy trying to make the transition as smooth as possible. Since the contracting is now carried out through the administration of the University of Hamburg new research affiliate agreements had to be negotiated. Several other matters necessary to run WIT also had to be moved from Karlsruhe to Hamburg. Not all of this went as unnoticed as we would have wished, but we are confident that with the transfer completed now we can once again offer you the smooth management you are used to from the past decade.

In many respects the 11th year of WIT was very successful. The WIT research team was extended by two new affiliate research partners. The seismic modelling team of NORSAR has joined us, thus strengthening the already established research ties between WIT and NORSAR. The NORSAR team will from now on contribute to the WIT meetings and reports. Moreover, NORSAR also kindly sponsors us by providing the NORSAR modelling software package to the WIT research team.

Our second new affiliate research partner is the group of Prof. Thomas Bohlen at the Technical University and Mining Academy of Freiberg, Germany. Thomas' team is working very successfully on the important topic of full waveform inversion. Although computationally demanding for 3-D data, it is a logical step after NIP-wave tomographic velocity model building and migration velocity analysis. We are grateful to Thomas' team for contributing to this report and to the 2008 WIT meeting.

In addition to our new research affiliate partners, we are pleased that the WIT research personnel is continuously enhanced by new M.Sc. and Ph.D. students joining our working groups. Also concerning education, Campinas University's Graduate Program in Petroleum Sciences and Engineering has started this year a new line on Reservoir Geophysics, in response to the market's strong demand of professionals in this area.

As in previous years, our research affiliate in Belém, Brazil, also contributed to the report.

A total of five new sponsors entered into WIT. RWE Dea and PGS as previous WIT sponsors already decided to rejoin WIT in 2007. As of 2008, we also welcome the three new sponsors Elnusa Geosains; Institut Teknologi Bandung (ITB), represented by EPTC Pertamina Research Cooperation; and Petrologic. We are looking forward to a fruitful cooperation with you. Two companies, Shell and Western-Geco, have decided to retreat. We would like to express our gratitude for their support in the past.

Three major events reflect landmarks of the last year for WIT. The 'Festygel', a conference in Campinas, Brazil, to celebrate Martin Tygel's 60th birthday was already briefly mentioned in the Annual Report 2006. In this volume, a more detailed coverage of this outstanding event is given further below.

Another important event took place right after the 2006 WIT meeting in Karlsruhe: The 'HubralFest', themed 'Making Waves about Seismics' was held to celebrate Peter Hubral's lifetime achievements and his retirement from the university. Many of you were able to participate in this event and a brief account is included in this volume. Our best wishes go with Peter for his retirement. We are convinced, though, that there will still be a lot of unrest and making waves, not restricted to WIT but also in the 'hidden roots of human creativity'.

It appears as a nice coincidence that the monograph on 'Seismic True-Amplitude Imaging' by Jörg Schleicher, Martin Tygel and Peter Hubral was published by the SEG in 2007. It represents not only a substantial part of Peter's and the co-authors' lifetime scientific achievements, but it is also an outstanding landmark of WIT research and a documentary on a long lasting German-Brazilian research cooperation.

While we are speaking about lifetime achievements, we are happy to share with you that Martin Tygel received the Lifetime Achievement Award of the Brazilian Geophysical Society (SBGf) in November 2007.

The award was presented to Martin during the 10th International SBGf Congress in Rio de Janeiro. Congratulations to Martin for this prestigious award, to which we have also dedicated a short report below.

We thank Norman Bleistein for kindly providing the coverage of these three events.

Finally, we want to express our sincere thanks to all of you for your continuous support of the WIT consortium. Your support is the foundation for all the scientific work you will find in this report. We would like you to know that your contributions are also vital in our mission to educate skilled graduate students who may one day continue their careers in your companies.

We will continue to make waves!

Dirk Gajewski

WORKSHOP HONORING MARTIN TYGEL'S 60TH BIRTHDAY

On November 8 and 9, 2006, a group of scientists with a broad interest centered on the theory and application of mathematics and physics to seismic modeling, migration and inversion gathered at Unicamp for a workshop – lovingly called Festygel by its attendees – in honor of Martin Tygel's 60th birthday. An eminent list of attendees from various countries came to honor Martin on this special occasion in recognition of his contributions to the development of improvements in the methods currently used in seismic data processing. Many of the presentations at the meeting used Martin's own work, often in collaboration with others, as their basis or as a contributing factor.

In addition, the Brazilian Geophysical Society (SBGf) honored Martin for his contributions to the education and training of young people in applied mathematics, in general, and in mathematical-geophysics, in particular. Martin travels around Brazil as a member of the thesis committees of students at other universities, thereby sharing his own insights broadly in Brazil. Martin is also a past president of the Brazilian Society of Applied and Computational Mathematics.

Martin's own talk at this meeting was about his philosophical view and approach to applied mathematics. The line to remember from that talk is, "If you think education is expensive, try ignorance!"

Norm Bleistein

True love, true friendship, true amplitudes – photos courtesy of Norm Bleistein and Judy Armstrong.

A photo album for Festygel can be found at http://cwp.mines.edu/ norm/Photos/Tygelfest/

WORKSHOP HONORING PETER HUBRAL

On February 28, 2007, a workshop, Hubralfest, was held at the University of Karlsruhe to honor Peter Hubral on his recent retirement from the university as Professor of Applied Geophysics. Peter has had a long and distinguished career in seismic inverse methods, making important contributions through his many papers, solely- and co-authored. He has also co-authored three monographs on the subject. He brings to his work his own unique insight into the graphic depiction of the relationship between the recorded seismic data and the related structure of the Earth. He was a founding member of the Wave Inversion Technology Consortium and its intellectual and inspirational leader for more than ten years. He has been honored with the EAEG Conrad Schlumberger and Erasmus Awards and the SEG Reginald Fessenden Award. Peter is an Honorary Member of the SEG and he also received the Nero Passos Award from the Brazilian Geophysical Society (SBGf). The prize recognizes SBGf members in Academics that have provided outstanding contributions to geophysics. It is also a recognition of the leading role Peter had in the development of geophysics in Brazil.

This workshop in honor of Peter was another in a series of worldwide workshops in the mathematics underlying methods of seismic data processing. There is a core group built around the members of the Wave Inversion Technology (WIT) program but supplemented by people elsewhere who share the same interests. This is their special thing, *la nostra cosa matematica di geofisica*, that brings them together periodically, catching up on one another's work and hearing about developments from other attendees. Such smaller, more intimate, meetings are a valuable adjunct to journals and international meetings for their efficient means of communication.

The workshop ended with a banquet at which Peter received many laudatory testimonials from the distinguished attendees.

Norm Bleistein

Photos courtesy of Norm Bleistein and Judy Armstrong.

LIFETIME ACHIEVEMENT AWARD FOR MARTIN TYGEL

The Brazilian Geophysical Society (SBGf), in its 10th International Congress held in Rio de Janeiro, at November 19–23, 2007, has presented Professor Martin Tygel – Institute of Mathematics, Statistics and Scientific Computing, State University of Campinas (IMECC/Unicamp) – with a lifetime achievement award for his outstanding career in the application of mathematics to problems in modeling, migration and inversion of seismic data. The award, called Nero Passos Award, is designed to recognize SBGf members in Academics that have provided outstanding contributions to geophysics.

Martin is one of the leading applied mathematicians, committed to advance the quality and breadth of education and research in exploration geophysics. A few years ago, he established the Laboratory of Computational Geophysics program at Unicamp. The Lab provides up-to-date facilities to develop the exploration geophysics research and development projects, in particular in the framework of the Wave Inversion Technology (WIT) Consortium. He explained his commitment by saying that he saw a need to train Brazilian students not only in the mathematics of exploration geophysics, but also in the computational implementation of their mathematical methodology.

As a researcher, he has collaborated with peers worldwide, addressing the extension of methods at the forefront of current technology in exploration geophysics and making important contributions to improve on those methods.

Norm Bleistein

Summary: WIT report 2007

IMAGING

Anikiev et al. apply a modified diffraction stack for the localisation of seismic events. Examples for data with a high noise level and near-surface complexities show that the technique yields reliable results for these situations. Furthermore, an additional example demonstrates that the method also leads to a good localisation accuracy even if the velocity model is not known.

Baykulov et al. applied CRS stack method to reflection data from the North German Basin which were recently released by the industry. The reprocessing of the data clearly demonstrates the capabilities of the CRS technique for low fold data. The images display a considerably improved SN ratio and show much more details than the CMP processing of the 1980s. Moreover, a velocity model consistent with the data was build and used to perform pre- and post-stack depth migrations which were so far not available for these data. The new depth images allowed an updated look on the petroleum system of the Glueckstadt Graben, which indicates new possible exploration targets.

Baykulov and Gajewski performed partial stacking of prestack seismic reflection data based on the kinematic wavefield attributes computed during the automatic CRS stack. The resulting CRS supergathers are more regularized and have better signal to noise ratio compared to original CMP gathers. The improved data can be used in any conventional processing tool instead of the original data, providing enhanced images of better quality. The CRS supergather method is especially suited for low fold seismic reflection data. Application of the new method to synthetic and real low fold data shows a clear improvement of seismograms as well as time and depth-migrated sections.

Bohlen et al. discuss a relatively new wave equation based imaging method that utilizes the full information content of the multi-component elastic wave field. The elastic parameters of the sub-surface are derived by an iterative tomographic inversion method. The resolution of the derived velocity models is in the order of the seismic wavelength. Applications to synthetic data sets demonstrate the outstanding imaging potential of the method.

Costa et al. propose a new, reflection-angle-based kind of smoothness constraint as regularization in slope tomography and compare its effects to three other, more conventional constraints. They find the smoothness constraints to have a distinct effect on the velocity model but a weaker effect on the migrated data. The new constraint leads to geologically more consistent models.

Dümmong and Gajewski are presenting two approaches for identification of surface related multiples within the CRS workflow. One approach focusses on the multiple identification with CRS attributes (i.e. the angle of incidence). The second one is based on the multiple prediction by autoconvolving each stacked trace with itself (hybrid SRME-CRS approach). Both approaches are tested on two synthetic data sets.

Gamboa et al. study the effect of enhancement of signal high frequencies on CMP and CRS stacked volumes. It is shown that high frequencies can be successfully recovered by means of the application of spectral whitening. Recovery is seen to be significantly better in CRS than in CMP stacked volumes.

Iversen and Tygel revisit the problem of time-to-depth conversion of a given time-migrated section and a time-migration velocity field. The study, which extends the previous work described in WIT Report 2006, is now fully 3D with an accompanying 3D synthetic example.

Lima et al. propose the use of a fourth-order "semblance" function as an alternative for the classical (second-order) semblance as a coherence measure to obtain CRS parameters from multicoverage data. Their first test show that this higher-order statistics measure better discriminates signal and noise, having, thus, the potential of producing cleaner sections and more reliable parameter estimates.

Meier et al. give a comparison between two tomographic inversion schemes, namely prestack stereotomography and NIP-wave tomography. The results are compared for two examples from a real marine dataset from the Eastern Mediterranean. One example focusses on the vertical resolution of the velocity model and the other one on the lateral resolution of the obtained velocity distribution. The differences are discussed with respect to the different inversion problem formulations.

Pila et al. derive a 2.5D true-amplitude diffraction-stack-type redatuming operator and present its specific form for zero-offset data. The operator consists of performing a single weighted stack along adequately chosen stacking lines. For simple types of media, they derive analytic expressions for the stacking lines and weight functions and demonstrate its functionality with numerical examples.

Schleicher et al. compare the effects of different imaging conditions for common-shot wave equation migration on the final migrated images after stack using the Marmousi data set. They confirm the conclusion from the single-shot experiments that the most robust imaging condition with illumination correction is the one that divides the crosscorrelation of the up- and downgoing wavefields by the autocorrelation of the downgoing wavefield.

Silva Neto et al. propose a new imaging condition with obliquity correction for reverse time migration. Its implementation requires the determination of the Poynting vector of the source and receiver wavefields at the image point. Numerical examples show that the obliquity correction reduces backscattering artifacts and improves the illumination compensation.

Tessmer and Gajewski investigate the influence of a scattering surface layer on the accuracy of reverse modelling event localization.

Ursin and Tygel discuss tuning and stretch effects that appear on AVO and AVA in the presence of a thin layer.

von Steht and Mann present a simple and efficient approach to calibrate the velocities at downhole receivers by means of walkover VSP data. This allows an accurate determination of emergence angles, as verified for wavefield decomposition.

MODELING

Freitas et al. describe a fast method for seismic ray tracing in a cellular model, in which cells can have general polynomial shapes with non-planar bounding faces. Numerical examples are shown using Mod2B, an interactive prototype editor.

Kashtan and Tessmer show that under certain conditions there is a Rayleigh wave which has a horizontal component of polarization perpendicular to its propagation direction. Numerical experiments using the pseudo-spectral Chebyshev method confirm this result. The amplitude of this wave is about 100 times smaller than that of the classical Rayleigh wave.

OTHER TOPICS

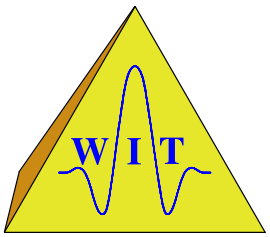
Gomes et al. describe the development of CRS Office, a friendly Java graphical user interface for the CRS stack processing code of Dr. Jürgen Mann released in Karlsruhe, Germany, and an example of application to synthetic and real marine data from offshore Brazil.

Feskova et al. present a hybrid modeling procedure involving 2D FD and ray tracing techniques. The approach assumes that the travel path can be determined in the geometrical optic limit. The applicability is demonstrated by numerical experiments of elastic wave propagation for models of different complexity.

Schleicher et al. discuss several different ways of extracting the desired slope information from the data. Based on the observation that the inverse of the local slope can also easily be extracted from the data, they propose a simple, straightforward correction to linear plane-wave destructors and study the extraction numerically.

Schleicher and Aleixo compare a number of traveltime approximations in VTI media that have been discussed in the literature and introduce a few new approximations. Some of the new traveltime formulas have rather simple analytic expressions and provide the same quality of approximation as the better of the established approximations.

The Wave Inversion Technology (WIT) Consortium



The Wave Inversion Technology Consortium (WIT) was established in 1997 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, members of the Institute of Geophysics of the TU Bergakademie Freiberg, Germany, and of NORSAR joined WIT as research affiliates.

The WIT Consortium offers the following services to its sponsors:

a.) research as described in the topic "Research aims" below;

b.) deliverables;

c.) technology transfer and training.

RESEARCH AIMS

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

1. Multi-parameter stacking and inversion
2. Macromodel determination
3. Seismic image and configuration transformations (data mapping)
4. True-amplitude imaging, migration and inversion
5. Seismic and acoustic methods in real media
6. Passive monitoring of fluid injection and production
7. Fast and accurate seismic forward modeling
8. Modeling, imaging and inversion in anisotropic media

WIT PUBLIC RELATIONS COMMITTEE

Name	University	Area
Claudia Vanelle	Hamburg	Administration and contact to representatives, WIT Report and WIT Software CD
Dirk Gajewski	Hamburg	Coordination and contact to representatives
Ekkehart Tessmer	Hamburg	WIT Homepage Manager
Jürgen Mann	Karlsruhe	Contact to representatives

STEERING COMMITTEES

Internal		External	
Name	University	Name	Sponsor
Dirk Gajewski	Hamburg	Roger L. Reagan	Anadarko
Tina Kaschwich	NORSAR	Paolo Marchetti	ENI
Jürgen Mann	Karlsruhe	Thomas Hertweck	Fugro Seismic Imaging
Jörg Schleicher	Campinas	Paul Krajewski	Gaz de France
Markus von Steht	Karlsruhe	Tamir Tal	Geomage
Ekkehart Tessmer	Hamburg	Dan Grygier	Landmark
Martin Tygel	Campinas	Martin Karrenbach	Paulsson Geophysical Services Inc. (P/GSI)
Claudia Vanelle	Hamburg	Eduardo Lopes de Faria	Petrobras
		Martin Widmaier	Petroleum Geo-Services (PGS)
		Matthias Riede	RWE Dea AG
		Ahmed Marzoug	Saudi Aramco
		François Audebert	Total S.A.
		Henning Trappe	TEEC

COMPUTING FACILITIES

The Hamburg group has access to a 24 nodes (8 CPUs and 64 GB each) NEC SX-6 supercomputer at the German Computer Center for Climate Research (Deutsches Klimarechenzentrum, DKRZ) for numerically intensive calculations, and also to a SUN Linux cluster with 256 nodes (2 dual core Opteron, 16 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 SUN workstations and Linux PCs.

The research activities of the Campinas Group are carried out in the Computational Geophysics Laboratory. The Lab has many PC Linux workstations and Sun Ultra 60/80 workstations connected by a dedicated 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 is being built in the new facilities of the Center of Petroleum Studies. The new Lab, expected to be in operation next year, will also have remote access to the computing facilities of the Petrobras Research Center in Rio de Janeiro.

In Karlsruhe, the research project uses computer facilities that consist of mainly Hewlett-Packard, Silicon Graphics, and Linux workstations. These are networked with a local compute server, a Silicon Graphics Origin 3200 (6 processors, 4 GB shared memory). For large-scale computational tasks, a Hewlett-Packard XC 6000 Linux cluster is available on campus. It is currently equipped with 128 nodes (allowing a theoretical peak power of 1.9 Tflops), 2 TB memory, and a 10 TB Lustre file system.

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

The Institute of Geophysics at TU Bergakademie Freiberg is equipped with 21 Linux PCs with Intel

dual- and quad-core processors. They are linked by GBit Ethernet and are used for small-scale computations. For large-scale computations, the Freiberg group has access to the Chemnitz High performance Linux Cluster (CHiC). Furthermore, it is planned to use the SGI Altix 4700 at the ZIH (Zentrum für Informationsdienste und Hochleistungsrechnen), TU Dresden.

WIT research personnel

Denis Anikiev is studying for a bachelor degree at the Department of Physics of Earth at St.Petersburg State University, Russia. He participated in an exchange program with Hamburg University in 2006,2007 during his work on the "Localization of Seismic Events by Diffraction Stacking". His present research interests include localization of seismic events, inverse problems for acoustic media, and virtual source technology. He is a student member of SEG, EAGE, SPE.

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

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

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

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

Denise De Nil received a diploma in geophysics from Ruhr-Universität Bochum in 2001 with a theoretical and numerical thesis on surface wave progation. From 2001 to 2006 she has been a research associate at Christian-Albrechts-Universität zu Kiel, where she has been involved with the development of new analyzing techniques for low quality data in ocean bottom, tunnel and borehole seismics. Since 2006 she is a research associate at Technische Universität Bergakademie Freiberg. Her present research focusses on tunnel seismics and numerical modeling of seismic wave propagation. She is a member of Deutsche Geophysikalische Gesellschaft.

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

Tatjana Feskova is diploma student at the Geophysical Institute, Karlsruhe University. Since 2006 she is a research student in the working group 'Seismic rock physics'. Her research topics include finite-differecne modeling and effective media theories.

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

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.

Anderson B. Gomes obtained his Bachelor Degree in Mathematics in 2004, and his Masters Degree in Geophysics in 2006, both in the University of Pará (UFPA), Brazil. Presently, he is a doctor student in the Graduate Course in Geophysics of UFPA in the area of seismic methods applied to oil and gas exploration. He is member of SEG and of SBGF.

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

Olaf Hellwig studied geophysics at TU Bergakademie Freiberg, Germany. Between 2004 and 2005 he spent one year at NTNU Trondheim, Norway. He received his diploma in geophysics in 2007. Since 2008 he is Ph.D. student in the Institute of Geophysics at TU Bergakademie Freiberg. His research interests focus on modeling of seismic wave propagation in boreholes and imaging of reflectors ahead of the drill.

Zeno Heilmann received his diploma in Geophysics from the University of Karlsruhe in October 2002. Since November 2002 he has been a research associate at the Geophysical Institute, Karlsruhe University. Besides the practical application of the CRS stack based imaging workflow in several research projects, he worked on the development of the CRS stack software, focusing on the influence of rugged topography and near surface velocity variations. He completed his PhD thesis in February 2007 and is member of EAGE and SEG.

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.

Stefan Jetschny received a Bachelor in Geophysics in 2003 at the TU Bergakademie Freiberg. After finishing internships at RWE Dea, Hamburg, Baker Hughes Inteq, Celle and Eastern Atlas, Berlin, he continued his studies in 2004 at the Institute of Geophysics, TU Bergakademie Freiberg. In 2005 he wrote his Diploma thesis at Baker Hughes Inteq in Houston, USA and received a Diploma (Master) in Geophysics in 2006 at the TU Bergakademie Freiberg. His research interests focus on LWD and wireline imaging tools, processing of borehole imaging data, 2D/3D seismic modelling of full elastic wavefields and the propagation of tunnel surface-waves. He is a member of DGG, SEG, AGU, EAGE and IAMG.

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.

Mareike Kienast is diploma student at the Geophysical Institute of Karlsruhe. She worked on the application of limited-aperture migration and completed her diploma in 2007. She is a member of EAGE.

Tilman Klüver received his diploma (with distinction) in geophysics from Karlsruhe University in February 2004. Since April 2004, he has been a research associate at Karlsruhe University. His research covers the application of kinematic wavefield attributes in 2D and 3D inversion schemes as well as their extraction from seismic datasets. He completed his doctoral thesis in June 2007. He is a member of the EAGE and the SEG.

Daniel Köhn received his diploma in geophysics from Kiel University in 2005 with a thesis on modeling of elastic waves by finite differences on a spatially variable grid. From 2005 to 2006 he has been a PhD student at the Institute of Geophysics at Kiel University, where he has been involved in the "Scherseis 3D" project funded by the German Research Society (DFG). Since 2007 he is a research associate at the Technische Universität Bergakademie Freiberg. His research interests are Time-Domain-Full-Waveform-Inversion and numerical modeling of seismic wave propagation.

André 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. Since 2007 he is a Ph.D. student at the Institute of Geophysics, TU Bergakademie Freiberg. His research interests focus on 2D seismic modelling of acoustic/elastic wavefields and 2D full waveform inversion applied to cross-hole tomography. He is a member of AGU, IAMG and EAGE.

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.

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

Jürgen Mann received his diploma in geophysics in 1998 from the Faculty of Physics, Karlsruhe University, with a thesis on Seismic Image Waves. In 2002, he received a doctorate in natural sciences (with distinction), again from the Faculty of Physics in Karlsruhe, with a thesis on the Common-Reflection-Surface Stack method. Since 1998 he has been a research associate at Karlsruhe University, from 2001 to 2006 he was assistant to Prof. Peter Hubral. His fields of interest are seismic reflection imaging methods, especially data-driven approaches based on kinematic wavefield attributes. He is active member of the SEG, member of the EAGE and its research committee, and member of the editorial board of the Journal of Seismic Exploration.

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

Joachim Miksat received a diploma in geophysics in 2002 from Karlsruhe University and his PhD in 2006 also from Karlsruhe University. Since then he is working as a post-doctoral fellow in Karlsruhe. His research interests include numerical modeling of seismic wave propagation and earthquake seismology.

Nils-Alexander Müller received his diploma in geophysics in December 2003 from Karlsruhe University, Germany. His thesis dealt with the implementation of the 3D CRS stack. Since 2004 he has been a research associate at the Geophysical Institute in Karlsruhe. His research covers the 3D CRS stack and the application of the kinematic wavefield attributes in 3D inversion algorithms. He received his doctorate in June 2007 and is a member of EAGE and SEG.

Tobias M. Müller received a diploma in geophysics in 1998 from Karlsruhe University and his PhD in 2001 from Free University Berlin. From 2002-2004 he has been a post-doctoral fellow of the Deutsche Forschungsgemeinschaft at Curtin University of Technology in Perth. Since 2005 he is head of the junior research group "seismic rock physics" at the Geophysical Institute, Karlsruhe University. His research interests include seismic waves in random media and rock physics. He is a member of DGG, EAGE, and SEG.

Nhi Nguyen received his MSc in Continuum mechanics from University of Liege, Belgium in 2002. He is expected to submit his PhD thesis in 2008 in Institute of Geophysics, University of Hamburg. His main research interests are full waveform inversion, seismic modeling, seismic wave propagation in seafloor, surface wave, borehole seismics.

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

Rodrigo Portugal received his B.Sc. (1995), M.Sc. (1998), and PhD (2002) in Applied Mathematics from the State University of Campinas (UNICAMP), Brasil. In his thesis he studied wavefront construction in the 2.5D situation and its application to the four Kirchhoff operations, namely: modeling, migration,

demigration and demodeling. Currently he is an associate researcher of the Department of Geology and Natural Resources (DGRN) at UNICAMP. His research interests include wavefront propagation, numerical analysis, seismic imaging and inversion.

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

Jörg Schleicher received a BSc (1985) in physics, an MSc (1990) in physics, and a PhD (1993) in geophysics from Karlsruhe University (KU), Germany. From 1990 to 1995, he was employed as a research fellow at KU's Geophysical Institute. From September 1995 to September 1996, he was a visiting scientist at the Institute for Mathematics, Statistics, and Scientific Computing of State University of Campinas (IMECC/UNICAMP) in Brazil with joint grants from the Brazilian Research Council CNPq and Alexander von Humboldt foundation. Since October 1996, he has been employed as an Associate Professor for Applied Mathematics at IMECC/UNICAMP. In 1998, he received SEG's J. Clarence Karcher Award. His research interests include all forward and inverse seismic methods, in particular Kirchhoff modeling and imaging, amplitude-preserving imaging methods, ray tracing, and model-independent stacking. He is a member of SEG, EAGE, DGG, SBGf, and SBMAC.

Miriam Spinner received her diploma in geophysics in December 2003 from Karlsruhe University, Germany. Her thesis dealt with an extension of true-amplitude Kirchhoff migration to handle data acquired on a measurement surface with topographic variations. Since 2004 she has been a research associate at the Geophysical Institute in Karlsruhe. Search interests include the CRS technique and limited-aperture migration in the context of AVO analysis. She completed her doctoral thesis in July 2007. She is a member of EAGE and SEG.

Ekkehart Tessmer received an MSc in 1983 in geophysics from Hamburg University and a PhD in 1990 from Hamburg University. Since 1990, he has been senior research scientist at the Institute of Geophysics at Hamburg University. Since 1994, he has a university staff position. His research interests include exploration seismology, seismic and electromagnetic wave propagation simulation, and migration. He is a member of DGG, EAGE, and SEG.

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.

Claudia Vanelle received her diploma in physics in 1997 and her Ph.D. in 2002, both from the University of Hamburg. Since 1997 she has been a research associate at the University of Hamburg and since 1998 at the Institute of Geophysics in Hamburg. In 2002 she received the Shell She-Study-Award in appreciation of her Ph.D. thesis. Her scientific interests focus on true-amplitude migration, ray method, and anisotropy. She is a member of EAGE and SEG.

Ines Veile is a new diploma student in the Karlsruhe WIT group. She will work on alternative strategies for minimum-aperture true-amplitude Kirchhoff depth migration. She is member of EAGE and SEG.

Markus von Steht received his diploma in geophysics in Febuary 2005 from the University of Karlsruhe (TH). The field of study focused on the handling of rugged topography in the CRS stack and its application to synthetic and real data. His current field of study is the development of a CO CRS stack to handle VSP and multi-component data. He will complete his doctoral thesis on this topic in early 2008. He is a member of the EAGE and SEG.

Mi-Kyung Yoon received her diploma from the Technical University of Berlin. From 2001 to 2005 she worked in the imaging group of the Free University of Berlin. She finished her PhD thesis in February, 2005. Since April 2005 she is working as a research scientist at the Institute of Geophysics in Hamburg.

List of WIT sponsors in 2007

Anadarko Petroleum Corp.
1201 Lake Robbins Dr.
The Woodlands, TX 77380
USA
Contact: Dr. Roger L. Reagan / Dr. Riaz Ala'i
Tel: +1 832 636 1347 / +1 832 636 1550
Fax: +1 832 636 8075
E-mail: Roger.Reagan,Riaz.Alai@anadarko.com

Eni - Divisione Exploration & Production
AESI/E&P
Via Emilia 1
20097 San Donato Milanese MI
Italy
Contact: Mr. Paolo Marchetti
Tel: +39 2 520 62827
Fax: +39 2 520 63891
E-mail: Paolo.Marchetti@eni.it

Fugro Seismic Imaging Ltd
Horizon House, Azalea Drive
Swanley, Kent BR8 8JR
United Kingdom
Contact: Dr. Thomas Hertweck
Tel: +44 1322 668011
Fax: +44 1322 613650
E-mail: Thomas.Hertweck@fugro-fsi.com

Gaz de France
Produktion Exploration Deutschland GmbH
Waldstr. 39
49808 Lingen
Germany
Contact: Mr. Paul Krajewski
Tel: +49 591 612381
Fax: +49 591 6127000
E-mail: P.Krajewski@gazdefrance-peg.com

Geomage 2003 Ltd.
Beit Lotem
Shilat Business Park
Modi'in 71700
Israel
Contact: Mr. Emil Guberman
Tel: +972 (8) - 979 0605
Fax: +972 (8) - 928 5525
E-mail: info@geomage.com

Landmark Graphics Corp.
1805 Shea Center Drive
Suite 400
Denver, CO 80129
USA
Contact: Mr. Dan Grygier
Tel: +1 303 488 3979
Fax: +1 303 796 0807
E-mail: DGrygier@lgc.com

Petrobras - CENPES/PDEX/GEOF
Av. Hum, quadra 7 s/n, Cidade Universitária
Illha do Fundão
CEP 21.941-598 - Rio de Janeiro, RJ
Brazil
Contact: Eduardo Lopes de Faria
Tel: +55 21 3865 4
Fax: +55 21 3865 4739
E-mail: Eduardo.Faria@petrobras.com.br

Paulsson Geophysical Services Inc. (P/GSI)
1215 West Lambert Road
Brea, CA 92821-2819
USA
Contact: Dr. Björn Paulsson, Dr. Martin Karrenbach
Tel: +1 562 697 9711
Fax. +1 562 697 9773
E-mail: Bjorn.Paulsson,Martin.Karrenbach@paulsson.com

PGS Geophysical AS
Strandveien 4
P.O. Box 354
1326 Lysaker
Norway
Contact: Dr. Martin Widmaier
Tel: +47 6751 4511
Fax. +47 6752 6640
E-mail: Martin.Widmaier@pgs.com

RWE Dea AG
Central Western Europe
Exploration
Überseering 40
22297 Hamburg
Germany
Contact: Dr. Matthias Riede
Tel: +49 40 6375 2166
Fax: +49 40 6375 3164
E-mail: Matthias.Riede@rwe.com

Saudi Aramco
Geophysical Research & Development Division
P.O. Box 750
Dhahran 31311
Saudi Arabia
Contact: Dr. Mohammed N. Alfaraj
Tel: +966 8747262
Fax: +966 38731020
E-mail: farajmn@mail.aramco.com.sa

TOTAL SA
Geophysical Operations and Technology
Avenue Larribau
64018 Pau Cedex
France
Contact: Dr. François Audebert
Tel: +33 5 59 83 52 71
Fax: +33 5 59 83 42 14
E-mail: Francois.Audebert@total.com

Trappe Erdöl Erdgas Consulting
Burgwedelerstr. 89
D-30916 Isernhagen HB
Germany
Contact: Dr. Henning Trappe
Tel: +49 511 724 0452
Fax. +49 511 724 0465
E-mail: Trappe@teec.de