SUMMARY REPORT

FORUM FOR

EXPLORATION AND DEVELOPMENT GEOPHYSICS EDUCATION AND RESEARCH

AT THE

UNIVERSITY OF TEXAS AT AUSTIN

Summary Report for Prospective Members:
EDGER Year 14 Term: June 1, 2013 - May 31, 2014

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UT-AUSTIN EDGER FORUM

Nurturing Education & Research for Tomorrow's Technology Needs at the Edge of Knowlege

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Executive Summary

We propose the continuation of the industry supported Geophysical Forum for Exploration and Development Geophysics Education and Research as part of an aggressive Exploration Geophysics Program at The University of Texas at Austin.

The EDGER Forum focuses on both the education and research aspects of developing tomorrow's leaders in the application of geophysical technologies to petroleum E&P activities.

Further, results of research undertaken by students and faculty are available for application by members of the Forum, and eventually widely disseminated by publication in professional journals. In addition, data bases supporting research and planning operations are being developed and maintained.

Benefits and Results of Participation

Research (Faculty & Student)

Benefits:

- ✓ Direct access to faculty, post-doc and MS and PhD student research results
- ✓ Establish research directions for faculty, student and post-doc research
- ✓ Cooperative projects between sponsors and EDGER researchers

Results for year Thirteen

- ✓ 2 PhD and 2 MS degrees completed during the past 12 months and 2 MS and 3 PhD anticipated by close of 2013
- ✓ 35 publications in 2012-2013
- ✓ Six active and two evolving cooperative research projects with sponsors

Proposed for year Fourteen:

- ✓ Continue established research directions
- ✓ Continue development of Focus Areas of Application
- ✓ Expand cooperative projects with sponsors, especially in applications for shale resources

Forum sponsored activities

Benefits:

- ✓ Participation in interdisciplinary Workshops and Symposia
- ✓ Exclusive access to broader elements of objective-oriented interpretative data base
- ✓ Direction in proposing industry workshops

Results for year Thirteen

- ✓ ***Annual Research Symposium: Seismic Characterization of Shales, Mudrocks and Tight Formations***
- ✓ Development of eight cooperative research projects
- ✓ Objective-oriented database of case histories maintained and updated

Proposed for year Fourteen:

- ✓ Continue annual technical symposium and interactive industry workshops
- ✓ Continue development of content and expand usage of the MC data base
- ✓ Conduct user workshops in Focus Areas of Application

Educational Activities

Benefits:

- ✓ Direct access to students
- ✓ Graduates employable by industry
- ✓ Cooperative student research projects

Results for year Thirteen:

- ✓ Seven new graduate students (6 new MS students and 1 new PhD student)
- ✓ 18 graduate students enrolled with focus on Exploration Geophysics in the Dept. of Geological Sciences
- ✓ 30 undergraduate students in Option II-Geophysics as of January 2013

Proposed for year Fourteen:

- ✓ Offers made to 4 new grad students (2 MS and 2 PhD) to begin graduate program in exploration geophysics in Fall 2013 during first round of offers
- ✓ Recruit new graduate students for Fall 2014 admission
- ✓ Continue sponsors' direct and ongoing participation in setting educational and research directions

Although organized and administered similar to research consortia at various institutions, the Forum for Exploration and Development Geophysics Education and Research (EDGER Forum) includes a focus on education as well as research. In this sense, accountability emphasizes both educational and specific research goals that create educational opportunities for the students. Opportunities, however, exist to conduct focused research projects, funded separately from the Forum.

With significant emphasis on education, participating companies may desire to consider funding at a broader level than an individual business unit that would benefit from the research effort. To that end, business units and corporate recruiting would benefit from increased availability of top-flight graduates in exploration geophysics.

The broad research direction of the EDGER Forum has historically been focused on imaging, inversion, interpretation and analysis of multi-component seismic reflection data. Significantly, this encompasses AVO analysis of P-P and mode-converted P-SV data to address fluid saturation and even permeability. These topics now include emphases on wave propagation modeling and rock physics. This overall research emphasis has evolved to include several Focus Areas of Application. The current focus area on unconventional resources has been enthusiastically received by our sponsors and continues to expand through active cooperative projects.

Participants in the UT-Forum have already played a significant role in establishing education directions for students, and this trend is expected to continue.

Forum activities also include workshops focused on implementation of emerging technology within the industry. The UT-EDGER Forum, associated with the academic unit of the Jackson School of Geosciences, is in a unique position to coordinate this type of activity between various aspects of the industry and the academic community. Many of these workshops are proposed by members.

Given the number of MS students in the program, research depth has been increased by having several MS students working on a common research area—a concept that is well suited to the emerging Focus Areas of Application. Further, we have expanded the research activities and depth of research with the relatively recent addition of Assistant Professor and Co-PI, Kyle Spikes, working on rock physics and its relation to seismic characterization.

Integrated Research and Education

Overview

As part of the evolution of both industry and academic perspectives, more and more emphasis is focused on integrated research topics and education subjects. The need to couple geophysics with geology and engineering, in a quantitative sense, tends to rise to the top of many discussions within industry, within academia, and in communication between the two realms.

Integrated Research

In order for integrated research to progress, a graduate student in geophysics must be able to speak at a minimum two "languages". The two additional languages may be engineering or geology, for example. Geophysics is the first, but he or she must be able to communicate fluently with engineers in order to understand needs of an engineer. To complete the task, the student must then effectively communicate back to the engineer what the capabilities and limitations are of a particular geophysical technique or dataset, and how to convert one type of data volume (e.g., impedance or velocity) to another (e.g., water saturation or porosity). If the second language is intended to be geology, the same rules hold, but relating geophysical attributes to geological interpretations becomes the focal point. This communication can only be possible if the researcher understands the scale, resolution, and underlying physical principles for all the data types and techniques, regardless of the languages. Moreover, the researcher must be aware that working in multiple disciplines requires expert knowledge in both fields in order to publish integrated research findings in journals or present technical talks at professional meetings.

Integrated Education

Geoscience research to link multiple disciplines must begin with education along similar guidelines. At the school and university level, this responsibility falls to the teaching faculty who must convey the importance of their primary specialties while simultaneously emphasizing the pertinence of a secondary area of expertise. This is a challenge in a structured course setting, but it can be done with the proper planning and support of several individuals. Ultimately, the goal is not to teach two or more topics but to teach the students the practice of working among whichever disciplines a particular research project may require.

Relevance to the EDGER Forum

Developing integrative research and education subjects falls within the goals of the Jackson School of Geosciences. Moreover, the petroleum industry appears to continually need new experts who are capable of leaving the confines of their own areas of expertise and reaching across barriers that are either artificial or in place for non-scientific reasons. The EDGER Forum is a location to provide the type of environment conducive to the integrated approaches necessary for cutting-edge geoscience research.

Cooperative Research Projects

Student projects addressing problems defined with EDGER Members and utilizing industry data have been quite successful in integrating geological and geophysical concepts for students and have significantly enhanced their education experiences.

Industry Relations

State of the Petroleum Industry

In the past few decades, the petroleum industry has experienced a gap in the age distribution of geoscientists in general and geophysicists in particular. This dearth of younger geophysicists is illustrated by a survey commissioned by the Society of Exploration Geophysicists and published (1999) in The Leading Edge, one of the Society's leading journals. Fully 50% of the respondents were over the age of 45 in 1999, and 75% of respondents reported 10 or more years of experience.

More recently, to improve industry / academic relations, further Bob Tatham and Prof. emeritus Manik Talwani of Rice University organized a half-day special session at the 2010 SEG meeting in Denver. The objective was to cooperatively address issues related to 'Interaction between Academia and Industry'. The session included about a dozen panelists representing a range of interests in both academic and industry organizations. One result of that event was continued meetings of the panelists (an ad hoc committee) and the evolution of a 'call to action' paper outlining the 'U.S. Human Resources Challenge for Earth Science Education and Energy Exploration and Exploitation' to encourage further development of earth scientists. Dr. Talwani and Ole Martinsen of Statoil coordinated the development of this paper on behalf of the entire working committee. A U.S. human resource challenge for Earth science education and energy exploration and exploitation, was published in The Leading Edge, v31, no6, in June 2012. It points out that the majority of current earth scientists in the U.S. will retire within 15 years (30-40% are currently retirement-eligible) and about 40-50% of the current workforce has fewer than five years of industry experience. Obviously, this dramatic gap in the experience of geoscientists reminds us that a critical need still exists to educate new geoscientists at all levels. The EDGER Forum addresses the 'shorter term issues' by supporting graduate education and research and supplying graduates in the time frame of fewer than 10 years and conducting research relevant to industry needs. Essential undergraduate education is focused on much longer time frames. For example, GeoFORCE is an experiential outreach program that prepares Texas high school students to become part of the geosciences workforce. The 'Earth is Calling' program has also been designed to engage students and raise awareness of career opportunities to college-bound high school students.

These reports underscore the critical need for trained geophysicists as more experienced personnel in the industry retire. The cyclic nature of commodity prices, which drive the business cycles of the industry, are often difficult to align with research and new graduates entering the industry. This year's new students will be entering the industry two or more years from now, and future personnel needs must be addressed in this context.

Industry Recruiting at UT-Austin

UT-Austin is on the recruiting list for most companies hiring geoscientists. Last year, over 40 companies representing a broad cross-section of the industry visited the department. One consistent question from the recruiters is, 'Where are the geophysicists?' The Exploration Geophysics Program and the EDGER Forum are designed to address this industry need.

UT Geology Foundation Support

The Jackson School of Geosciences at The University of Texas at Austin unites one of the largest and most respected academic departments of geological sciences with two world-renowned research units, the Institute for Geophysics and the Bureau of Economic Geology. This combination provides a strong tradition of basic collaborative research with a robust program of applied research. Under its strategic plan, the school has many new faculty and scientists as part of a five year program with the goal of becoming the preeminent geoscience program in the United States.

Beyond general endowments dedicated to Exploration Geophysics, a major full-year graduate student fellowship is permanently endowed by the UT Geology Foundation since 1999 as part of the original 'Exploration Geophysics Initiative.'

This endowed fellowship, part of the proposed industry support of the Forum, is competitive with any other in the country and ensures the highest quality applicants are attracted to the Exploration Geophysics program at UT. Endowments totaling several million dollars, focused on aspects of Exploration Geophysics, reside in the Geology Foundation. This support of the overall Exploration Geophysics program provides a sound base and offers significant leverage for the funding provided by the EDGER Forum.

Fellowships and Awards (UT and Industry)

The 'Exploration Geophysics Fellowship' was endowed by an anonymous donor to encourage a strong applicant to enter the Exploration Geophysics program. This fellowship is offered to an entering student each year. Recipients of The 'Exploration Geophysics Fellowship' award are as follows:

TBD	2013
Sarah Coyle	2012
Russell Carter	2011
Alexander Lamb	2010
Corey Joy	2009
Robert Brown	2008
Travis Richards	2007
Anisa Perez	2006
William Burnett	2005
Christopher Sine	2004
Sharon Goehring	2003
Patricia Yu	2002
Matthew Morris	2001
Jason Gumble	2000

Industry and philanthropic donors have also provided a number of other significant fellowships to graduate students since the start of the EDGER Forum over a decade ago, including BP, Chevron, ConocoPhillips, Marathon, GXT, Hess, Saudi Aramco, Shell, Banks Memorial, Teagle, John Buck, Gale White, Fullbright, Ewing / Wurtzel, Cullinan, Questar and the Barrow Graduate Fellowship.

Industry Input and Direction

To ensure that the 'Exploration Geophysics Initiative' meets the needs of the petroleum industry, the Department of Geological Sciences hosted a symposium to assess the needs and expectations of potential industry participants. This 'Year Zero' symposium, held in December 1999, became the first in a series of technical symposia that form a central component of the EDGER Forum. Annual Symposia since that date have enhanced the research conducted by the EDGER Forum.

Faculty, Facilities and Infrastructure

Faculty and Facilities

As part of the overall geophysics faculty of six individuals, The Dept. of Geological Sciences has three full-time faculty members with a focus in Exploration Geophysics. Dr. Robert H. Tatham joined the faculty in 1999 as a professor, and Dr. Kyle T. Spikes joined the faculty in 2009 as an assistant professor. Dr. Mrinal Sen, working with the UT Institute for Geophysics (UTIG), has a 50% appointment as a professor in the Dept. of Geological Sciences and is actively involved with the EDGER Forum as Co-PI. Dr. Paul L. Stoffa also advises graduate students with a focus in Exploration Geophysics, as does Dr. Clark Wilson in the Dept. of Geological Sciences. Dr. Sergey Fomel, with the Bureau of Economic Geology, is a professor of the faculty of the Department of Geological Sciences, and he also advises students focused on Exploration Geophysics.

Facilities

Much of the infrastructure for Exploration Geophysics is housed in the L. Decker Dawson Exploration Geophysics Training Center in the Jackson Geological Sciences building. A limited number of graduate students are also 'housed' at the UT Institute for Geophysics on the J. J. Pickle Research Campus.

3D Seismic Interpretation Lab

The 3D seismic interpretation laboratory was completed in the Fall of 1999 and hardware and software are routinely refreshed. Courses utilizing this facility are now offered regularly. Graduate students in both Exploration Geophysics and 'soft rock' geology routinely use the lab. Recently, the 3D Seismic Interpretation Laboratory was completely refreshed with Linux-based workstations and a centralized software system maintenance capability. The central data storage capability with high-speed network capability remains. This hardware renewal was supported by endowments established specifically for providing students with state-of-the art computational capabilities.

Funding for operation of this laboratory is not a part of the proposed funds to be provided by the Forum. It comes primarily from endowed accounts within the Jackson School.

The 3D seismic interpretation lab provides educational opportunities to both undergraduate and graduate students in all areas of geology, geophysics and petroleum engineering. We anticipate that over time additional students from all the above areas will enroll in courses involving the lab. We believe a synergistic interaction between these students will evolve as a result.

Graduate students in soft-rock and petroleum geology also conduct thesis research on 3D data sets in the lab. Thus, the laboratory supports a wide cross-section of students and provides a place for interaction among students in many petroleum-related disciplines.

Geophysical Analysis and Interpretation Capability

In addition to the 3D seismic interpretation lab, computationally intensive workstations have been installed for use by graduate students in geosciences, including the Exploration Geophysics program. These workstations, tied to the high-speed storage area network shared by the 3D seismic interpretation lab, have computational and storage capability to accommodate pre-stack multicomponent 3D data sets. Additional workstations will be added as more graduate students join the Exploration Geophysics program.

Software and Data Support Manager

We have added an Applications Software Manager to the staff to support the wide variety of programs available to the Forum as well as to maintain the seismic data sets available. Initial funding came from a grant made by the UT Geology Foundation to the EDGER Forum to provide leveraged financial support to initiate this infrastructure. The position is now partially funded by the EDGER Forum. Presently the Exploration Geophysics Program and UTIG also support the position. This capability is crucial to the success of cooperative projects applying industry data, especially with MS students who are here for only a few semesters.

3D Seismic and Well Data Sets Available

Several 3D seismic data sets are available for educational use in the interpretation laboratory and student research projects. Some of these data sets include nearly complete subsurface log and production data. These data sets are an important industry contribution to the education and research programs in the Jackson School of Geosciences.

3D data sets currently available for student use by company name and area

- ***Chevron:***
- East Texas data set
- Louisiana State lease 30 and OCS 310, including complete log data. (Used for both education and research purposes).
- Garden Island Bay Field
- Port Neches Field

ExxonMobil:
- South Timbalier area, offshore Louisiana.

BP:
- East Texas data set
- Gulf of Mexico 3-D data set
- Forties Field (North Sea)
- Atlantis 3D-4C ocean-bottom (Nodes) data set.

PGS:
- West Africa, 3-D data set.
- West Cameron 3D 4C volume.
- Gulf of Mexico 4C pre-stack vol.

WesternGeco:
- Matagorda Bay 3D shoot

ERCH:
- Teal South 3D-4C time lapse data set **The EDGER Forum is the repository for the Teal South Data.**

Colo. School of Mines:
- Use of the Joffre 3D-9C data set.
- Weyburn Field P-SV Data set.

Anadarko
- Maro Polo 3D pre-stack data
- Donotello 3D-3C and VSP data set

Kerogen Resources
- Bakken Shale Dipole Logs & 3C Surface Seismic data

CGGVeritas
- 3C data set - Anadarko Basin

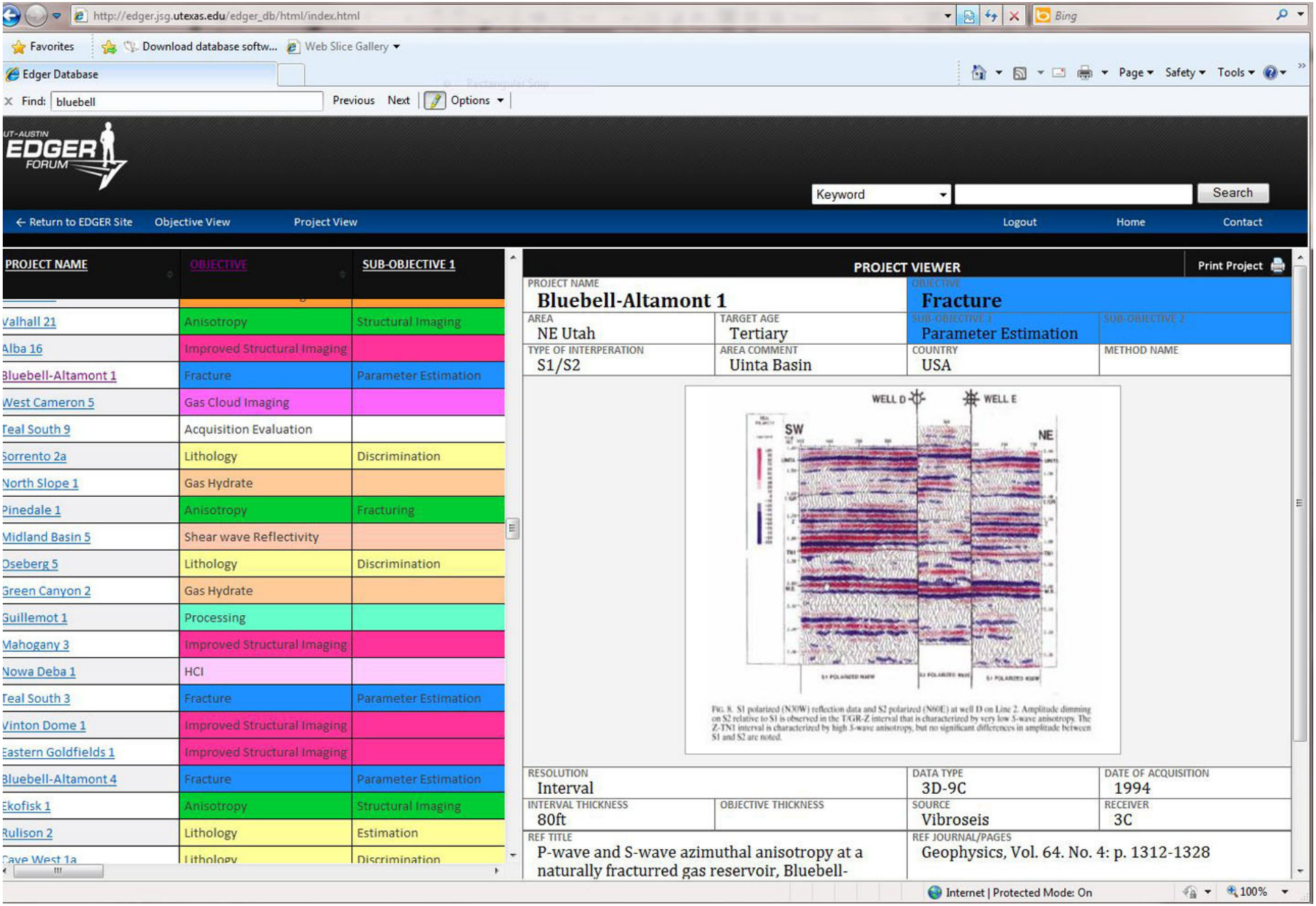


FIG. 8. S1 polarized (N30W) reflection data and S2 polarized (N60E) at well D on Line 2. Amplitude dimming on S2 relative to S1 is observed in the T/GR-Z interval that is characterized by very low S-wave anisotropy. The Z-TN1 interval is characterized by high S-wave anisotropy, but no significant differences in amplitude between S1 and S2 are noted.

Data Base of Multicomponent Seismic Interpretation Successes

The entry point of the data base is located within the EDGER website at the following URL:

http://edger.jsg.utexas.edu/edger_db

One of the common problems in implementing new technology is the education of the end user on actually applying the technology. This is particularly true for multicomponent seismic methods. Often technology developers understand the new application, but fail to fully educate the implementers on its ultimate implementation. This database is an attempt to assist in the technology transfer and education process.

The database allows potential users to search for actual examples of applications that are similar to their own problem. To this end, the database is organized with the intention of addressing specific exploration or development objectives and problems by providing a value-added database that catalogues successful shear wave interpretations from published sources. Work on this project has been conducted over many summers with undergraduate work-study students and graduate students supported by the Forum. To date, about 500 published real-data examples are included—with about a thousand examples anticipated. These examples are organized to allow searches based on survey objectives, and thus are 'problem oriented.' At the present time, the data base is being maintained, but new entries are at a reduced level.

The purpose of the database is to provide EDGER Forum members, and UT-Austin students and researchers, exclusive access to details of results from existing work in the interpretation and analysis of multicomponent seismic data. This has proven invaluable in planning multicomponent seismic projects, particularly 4C marine projects.

Guest ID's and passwords are available for temporary examination of the entire database by prospective members.

Objective oriented browser:
The primary user access to the database is through the Objective oriented browser. The entries can be sorted on a number of variables, including: project name, exploration or development objective (including two sub-objectives), the interpretative method applied and the actual multicomponent data type. The browser includes a comprehensive project listing in the left frame, and an interpretive summary on a selected entry in the right frame.

The objective oriented browser has recently been completely updated and additional content for the database is continuously being added.

An example of an entry is illustrated on the previous page. By default, the Project List is sorted by Project Name, however users can also click the heading to toggle the order. To sort on more than one field, the user holds down the Shift key on the keyboard and clicks on the appropriate heading to filter the results. There is also an internal search engine for filtering the data.

Students in Exploration Geophysics

For the upcoming academic year, including graduate students who have tentatively accepted offers, the current graduate student body with an interest in exploration geophysics is 22 for Fall 2013. We have also had a number of visiting graduate students from international universities, including one current visiting scholar who will be working with Dr. Tatham and Dr. Sen for the next year and one who worked with Dr. Spikes in the last half of 2012.

Academic Year	New Students Entered	MS Graduated	PhD Graduated
1996-99	3	1	0
2000/01	1	0	0
2001/02	2	1	1
2002/03	5	1	1
2003/04	3	1	0
2004/05	7	2	1
2005/06	8	3	2
2006/07	6	9	1
2007/08	2	5	2
2008/09	7	3	2
2009/10	7	4	3
2010/11	8	3	2
2011/12	3	2	1
2012/13	7	2*	2*
2013/14	TBD		

**to date*

We have a number of very qualified applicants for graduate admission for Fall 2013 and are pleased to have 4 new students tentatively accepted for adminssion during the first round of offers. The EDGER Forum is a major source of funding for many of our students, and this present pool of applicants presents our industry partners a great opportunity for recruitment from a strong class graduating in the 2013-2015 time frame. We target on average six new graduate student admissions for each academic year. With the support provided by recent new sponsors, we exceeded this goal in Fall 2012 and intend to meet it in Fall 2013. With increased industry support through the EDGER Forum, we are able to support more graduate students, with the potential of 8-10 graduating each year. These students work specifically on exploration geophysics problems and ultimately are employable by industry.

There are presently 30 undergraduate students who have declared Geophysics (Option II) as their major. With the establishment of the Jackson School of Geosciences as a college level entity in 2005, the undergraduate enrollment in Geosciences has increased significantly, particularly for entering freshmen.

One direction that has evolved in developing MS thesis topics is cooperative projects with industry sponsors. Several of these projects during the current year focus on an area of interest with applications to address seismic characterization of unconventional resources. As a result of the Technical Symposia and Annual Meetings of 2011 and 2012, several new cooperative project are now in progress. Projects to date (in the Woodford, Marcellus and Haynesville shales and the Cranfield carbon sequestration project) involve students working with an industry sponsor, ideally including a summer internship with the company, using log and surface seismic data to address the seismic response to optimal producing areas in unconventional production. Students gain first-hand experience with companies on actual exploration and development projects. Such cooperative projects may accomplish many of the objectives of the professional MS graduate with a full thesis and research experience.

Overall, the Exploration Geophysics Program must maintain enough breadth to ensure proper education while simultaneously providing enough focus on meaningful research topics for graduate students, post-doctoral candidates and supporting faculty. This focused research will provide useful technology for application by sponsors.

Students in Geological Sciences

We are often asked how many students are in Geological Sciences at UT Austin and how many are on international visas. In academic year 2012/13, the distribution of students in the Dept of Geological Sciences is as follows:

	US	Visa	Total
Undergrad	273	18	291
Graduate	184	98	282
Total	457	116	573

Industry Internships

Summer 2013 (to date)	**Year 14**
Lauren Becker	Marathon Oil
Russell Carter	ConocoPhillips
Sarah Coyle	ExxonMobil
Meijuan Jiang	Shell
Jacqueline Maleski	ConocoPhillips
Qi Ren	Chevron
Summer 2012	**Year 13**
Lauren Becker	Cabot Oil & Gas
Russell Carter	ConocoPhillips
Qi Ren	Chevron
Meijuan Jiang	Shell
Yang Xue	Shell
Kumar Das	NGRI, India
Summer 2011	**Year 12**
Alexander Lamb	Devon
Xiaolei Song	Chevron
Terence Campbell	ConocoPhillips
Yi Tao	ConocoPhillips
Yang Xue	Shell
Summer 2010	**Year 11**
Terence Campbell	Hess
Na Shan	ION-GXT
Vladimir Bashkardin	Total E&P
Yu Xia	ION-GXT
Yi Tao	ConocoPhillips
Corey Joy	BP
William Burnett	ConocoPhillips
Summer 2009	**Year 10**
Vladimir Baskardin	Chevron
Rob Brown	Marathon
William Burnett	ExxonMobil
Diego Valentin	Anadarko
Yang Wang	ExxonMobil
Fang Ye	BP
Summer 2008	**Year 9**
Adam Alan (Undergrad)	Kerogen Res
Vladimir Baskardin	GXT
William Burnett	ExxonMobil
Chunlei Chu	BP
Jeffrey Kao	Nexen
Travis Richards	Swift Energy
Alireza Shahin	Swift Energy
Samik Sil	Chevron
Sandy Suhardja	GXT
Fang Ye	Kerogen Res
Summer of 2007	**Year 8**
Tiangcong Hong	BP
Chaoshun Hu	Chevron
Anisa Perez	ConocoPhillips
Samik Sil	GW Systems
Daniel Smith	ExxonMobil
Sanjay Sood	GXT
Summer of 2006	**Year 7**
Engin Alkan	Dawson
Reeshidev Bansal	Chevron
Will Burnett	BP
Samarjit Chakraborty	ExxonMobil
Thomas Lovitz	Marathon
Emily Pangborn	ConocoPhillips
Chris Sine	Chevron
Sanjay Sood	GXT
Summer of 2005	**Year 6**
Chandan Kumar	BP
Samarjit Chakraborty	BP
Kimberly Kumar	BP
Matt McDonald	Shell
Christopher Sine	Anadarko
Jason Stephens	ConocoPhillips
Russell Young	ConocoPhillips
Summer of 2004	**Year 5**
Eric Lyons	Marathon
Sharon Goehring	ConocoPhillips
Summer of 2003	**Year 4**
Jason Gumble	WesternGeco
Patricia Yu	Marathon
Eric Lyons	Marathon
Eric Swanson	Dawson
Summer 2002	**Year 3**
Matt Morris	BP
Jason Stine	Conoco
Eric Lyons	Marathon
Summer 2001	**Year 2**
Jason Stine	BP
Jason Gumble	BP
Summer 2000	**Year 1**
Fernando Cerda	Phillips

Current Graduate Students with a focus in Exploration Geophysics

1 March 2013

Student	Advisor	Degree Obj.	Research Comments
Sarah Coyle BS Geosciences / Geophysics University of Texas at Austin '12	Spikes Ent. Fall '12	Currently Enrolled MS Student	*Inversion of seismic data with and without rock typing*
Lauren Becker BS Geosciences / Geophysics University of Texas at Austin '12	Spikes Ent. Fall '12	Currently Enrolled MS Student	*Finite-element simulations of fracture networks*
Patrick Gustie BA Earth & Planetary Sci /Geophysics University of California, Berkley '12	Tatham Ent. Fall '12	Currently Enrolled MS Student	*Identifying seismic attributes to estimate vertical transverse isotropy*
Jacqueline Maleski BS Geology University of Georgia '12	Tatham Ent. Fall '12	Currently Enrolled MS Student	*Application of Alford rotation to multi offset data*
Makoto Sadahiro BA Computer Science University of Texas at Austin '02	Tatham/Stoffa Ent. Fall '12	Currently Enrolled MS Student	*Processing algorithm development (Reverse Time Migration)*
Han Liu BS Geololgy & Geophysics Missouri Univ of Sci. & Tech '12	Spikes Ent. Fall '12	Currently Enrolled PhD Student	*Numerical modeling of complex pore shapes*
Karl Stetten Visiting Student from Norway Norwegian University of Science and Technology (NTNU)	Tatham/Stoffa Ent. Fall '12	Visiting MS Student	*Time-lapse seismic characterization of reservoir production*
Qi Ren BS Applied Physics University of Sci/ & Tech (USTC) '10	Spikes/Sen Ent. Spring '12	Currently Enrolled PhD Student	*Seismogram synthesis,imaging, and rock physics*
Jiao Xue MS Geophy Prospe & Inf. Tech China Univ of Geosciences, China '08	Tatham/Sen Ent. Fall '11	Visiting PhD (Candidate) Student	*Applications of AVO anisotropy to estimate fracture characteristics in subsurface reservoirs*
Zeyu Zhao BS Geophysics University of Petroleum, China '11	Sen Ent. Fall' 11	Currently Enrolled PhD Student	*Sub-basalt imaging with wide-aperture seismic data*
Yawen He BS Geophysics University of Petroleum, China '11	Hongliu Zeng/Sen Ent. Fall '11	Currently Enrolled PhD Student	*Reservoir monitoring of seismic facies*

Current Graduate Students with a focus in Exploration Geophysics

1 March 2013

Student	Advisor	Degree Obj.	Research Comments
Shaunak Ghosh MS Geophysics Indian Inst. of Tech Kharagpur ‘11	Fomel Ent. Fall ‘11	Currently Enrolled PhD Student	*2D and 3D velocity independent imaging techniques in the t-x and tau-p domain*
Sharif Munjur Morshed MS Petroleum Geology Geophysics University of Dhaka ‘10	Tatham Ent. Fall ‘10	Currently Enrolled MS Student	*Seismic anisotropy of the Marcellus Shale*
Meijuan Jiang MS Statistics University of Illinois ‘10	Spikes Ent. Fall ‘10	Currently Enrolled PhD (Candidate) Student	*Rock physics and seismic characterization of the Haynesville Shale*
Kumar Sundaram Das MS Applied Geophysics Indian Institute of Technology ‘08	Sen Ent. Fall ‘10	Currently Enrolled MS Student	*Joint inversion of seismic and gravity data for determination of the structure of Shiva Crater, India*
Russell W. Carter BS Geology Colgate University ‘07	Spikes Ent. Fall ‘10	Currently Enrolled PhD (Candidate) Student	*Reservoir chracterization for carbon sequestration*
Yang Xue MS Geophysics University of Stuttgart ‘07	Sen Ent. Fall ‘09	Currently Enrolled PhD (Candidate) Student	*Bayesian inversion of land multi-component data*
Terence A. Campbell MS Geology UT Austin ‘07	Tatham/Sen Ent. Fall ‘09	Currently Enrolled PhD (Candidate) Student	*Corrections for distortion polarization in reflected shearwave for isotrapic and anisotropic medium*
Xiaolei Song MS Geophysics Peking University ‘08	Fomel Ent. Fall ‘08	Currently Enrolled PhD (Candidate) Student	*Subsalt seismic imaging and velocity estimation using Fourier Finite Difference Method*
Mohammed Alhussain MS Geophysics Curtain University ‘08	Sen Ent. Fall ‘08	Currently Enrolled PhD (Candidate) Student	*Frequency dependent anisotropy*
Vladimir Bashkardin BS Mining Engineering Gubkin Academy ‘02	Stoffa/Fomel Ent. Fall ‘07	Currently Enrolled PhD (Candidate) Student	*Slope tomographic method in an Eulerian framework for seismic macro-velocity estimation*

UT Alumni
Graduates of the EDGER Forum Program

August 2000 - Dec 2012

Student	Advisor	Current Position	Research Comments
Yi Tao MS Geophysics Chinese Academy of Science '08	Sen Ent. Fall '08	PhD Dec 2012 ConocoPhillips (Houston)	*Seismic inferometry and inversion*
Engin Alkan MS Geophysics UT Austin '07	Hardage Ent. Fall '10	PhD Dec 2012 Shell (Houston)	*Elastic seismic stratigraphy*
Alexander P. Lamb BS Physics / Info. & Comp. Sci. University of California, Irvine '08	Tatham Ent. Fall '10	MS May 2012 Devon (Oklahoma City)	*Characterization of Woodford Shale*
Kwon Taek Oh BS Chemical Engineering Chungnam National University '94	Spikes Ent. Fall '10	MS May 2012 Korea Gas Corporation	*Pore shape estimation from seismic velocity in the Haynesville Shale*
Corey Joy BS Engineering University of Texas at Austin '09	Sen Ent. Fall '06	MS Augurst 2011 BP (Houston)	*Effective medium modeling of carbon sequestered reservoirs*
Son Phan BS Geophysics University of Tulsa, Oklahoma'09	Sen Ent. Fall '09	MS August 2011 BiendongPOC (Vietnam)	*Uncertainty in reservoir parameter estimation*
Alireza Shahin MS Petroleum Expl. & Engineering Univesity of Tehran '02	Stoffa/Tatham Ent. Spring '06	PhD May 2011 BP (Houston)	*Time lapse seismic response to production*
William Burnett MS Geophysics UT-Austin '07	Fomel/Stoffa Ent. Fall '05	PhD May 2011 ExxonMobil (Houston)	*Multi-azimuth velocity analysis using velocy-independent seismic imaging*
Tao Liu BS Geophysics/Economics Beijing University '06	Sen Ent. Fall '09	PhD (Candidate) Visiting PhD Student (2009-2010)	*Hybrid finite difference-finite element of seismic wave propagation*
Diego Valentin BS. Geology Univ. Nat Colombia. '08	Tatham Ent. Fall '08	MS Aug 2010 Gran Tierra Energy (Bogotá)	*Bossier Reservoir characterization with multicomponent VSP and surface seismic data*
Fang (Fiona) Ye ME Geophysics. Ocean Univ. (PRC) '03	Tatham Ent. Spring '08	MS May 2010 BP (Houston)	*Fracture estimation in the Bakken Shale from 3C-3D data.*
Jeffrey Chung-Chen Kao BS Geophysics University of Texas at Austin '05	Tatham Ent. Fall '01/Fall '07	MS December 2009 Nexen (Dallas)	*Deep water GOM - pore pressure estimation using P-SV Waves from multicomponent seismic in Atlantis Field*
Chunlei Chu ME Geophysics Ocean Univ of China '03	Stoffa Ent. Fall '05	PhD Dec. 2009 ConocoPhillips (Houston)	*Application of variable grid finite differences to seismic imaging and modeling*
Samik Sil MS Geophysics Univ of Alaska '06	Sen Ent. Fall '06	PhD May 2009 ConocoPhillips (Houston)	*Two-way travel time analysis for seismic reservoir characterization*
Jonas De Dio De Basabe Delgad MS Computational & Applied Math UT-Austin '07	Sen / Wheeler Ent. Fall '07	PhD May 2009 Ctr for Sci Research & Higher Education (Ensenada, Baja CA)	*Numerical simulation of elastic wave propagation* *UTIG Fellow*
Anisa Perez BS Geophysics Rice Univ '06	Tatham / Ferguson- C.Mosher Ent. Fall '06	MS May 2009 ConocoPhillips (Houston)	*Azimuthal analysis of hybrid gatherers*

UT Alumni
Graduates of the EDGER Forum Program

August 2000 - Dec 2012

Student	Advisor	Current Position	Research Comments
Chaoshun Hu MS Petroleum Engineering 2005 UT-Austin '05	Stoffa / McIntosh Ent. Fall '03 & '05	PhD Dec 2008 Chevron (San Ramon)	*OBS and MCS data analysis for TAIGER Project, offshore Japan*
Daniel Ryan Smith BS Geophysics Univ of Utah '06	Sen Ent. Fall '06	MS Aug. 2008 Hess (Houston)	*Seismic trace regularization and datuming*
Tiancong Hong BS Geoscience Penn State '04	Sen Ent. Fall '04	PhD Aug. 2008 ExxonMobil (Houston)	*MCMC algorithm, integrated 4D seismic res. char. and uncertainty analysis in a Bayesian framework*
Ali Al-Jadhar MS Geophysics King Fahd University of Petroleum	Stoffa Ent. Fall '06	MS Aug 2008 SaudiAramco (Dharan)	*Prestack modeling of carbonate reservoirs* *Saudi Aramco Scholar*
Abdulaziz Al-Muhadib BS Geology Univ of Tulsa	Sen / Tatham Ent. Fall '06	MS Aug. 2008 PhD Student MIT	*Post-stack inversion for porosity estimation of carbonate reservoirs* *Saudi Aramco Scholar*
Sanjay Sood MS Geophysics Punjab Univ India	Sen / van Avendonk Ent. Fall '04	MS Dec 2007 ConocoPhillips (Houston)	*Estimation of Q from seismic refractions data*
Patricia Yu BS EPS, Berkeley '02	Ferguson Ent. Fall '02	MS Dec 2007 Shell (Houston)	*Amplitude preservation in processing and imaging of seismic data*
Emily Marleah Pangborn BS Industrial Engineering Cornell University '05	Bangs / Tatham Ent. Fall '05	MS Dec 2007 Chevron (Houston)	*Thrust fault from 3D seismic: Nankai Subduction Zone, Japan.*
Nedra Bonal BS Geophysics New Mexico Tech. '00	Wilson Ent. Sp. '02	PhD Dec 2007 Sandia Nat Lb (Albuquerque)	*Fracture characterization: studies of seismic anisotropy and trace imaging with GPR.*
Engin Alkan BS Geological Eng. Ankara University	Hardage Ent. Fall '05	MS Aug 2007 PhD Student (UT-Austin)	*Acquisition design of 3D multicomponent surveys on land* *Turkish Nat. Oil Co. Scholar*
William Burnett BS Geophysical Eng. Colo. Sch. Mines 05	Ferguson Ent. Fall '05	MS May 07/ PhD 2011 ExxonMobil (Houston)	*A general transform for reversible seismic data processing* *Exploration Geophysics Fellowship ('05)*
Reeshidev Bansal MS Geophyics Virginia Tech . '03	Sen Ent. Fall '03	PhD May 2007 ExxonMobil (Houston)	*Seismic characterization of naturally fractured reservoirs*
Samarjit Chakraborty MS, Geophysics Indian Inst of Technology (IIT) '02	Ferguson Ent. Fall '02	MS May 2007 BP (Houston)	*An int. geologic model of the Valhall Oil Field for simulation of fluid flow and seismic response*
Christopher Robert Sine BS Geology Northern Arizona University '04	Grand Ent. Fall '04	MS May 2007 Occidental (Bakersfield)	*Tomographic velocity interpretation of the Upper Mantle, Colo Plateau*
Kevin Alan Bain BS, Physics UT-Austin, '01	Tatham Ent. Fall '01 & '05	MS May 2007 UT-PhD Stud. (Physics)	*Sensitivity of AVA reflectivity to fluid hydrocarbon properties in Porous Media*
Gregory Russell Young BS Geology & Math Centenary College of Louisiana '04	Sen Ent. Fall '04	MS May 2007 ExxonMobil (Houston)	*Effective porosity estimation from 3D seismic: Marco Polo Fld.* *ConocoPhillips Fellowship ('04)*

Student	Advisor	Current Position	Research Comments
Kathryn Teresa Young BS Electrical Engineering Universtiy of West Indies '04	Tatham Ent. Fall '04	MS Dec. 2006 BP. (Houston)	*False 'bright spots' and discriminating gas and brine using AVO* *Fullbright Scholar*
Matt McDonald BS Physics Brigham Young University '03	Tatham / Gulick (UTIG) Ent. Fall '04	MS Dec. 2006 Shell (Houston)	*The Chicxulub impact crater and oblique impact*
Eric Lyons BS Geophysics UT-Austin '02	Tatham Ent. Fall '98 & '02	MS Dec. 2006 ConocoPhillips (Houston)	*Polarization distortion of shear waves in isotropic media*
Jason Gumble BS Geophysics Colorado School of Mines '00	Tatham Ent. Fall '00	PhD Dec. 2006 Cimarex (Denver)	*Anisotropic analysis of 3C data for OBC and comparison to 9C. / ACS-PRF Funded Dissertation / Expl.Geophysics Fellowship ('00)*
Chandan Kumar BS Geophysics Indian Inst. of Technology (IIT) '02	Ferguson / Sen Ent. Fall '02	PhD Dec. 2006 BP (Houston)	*Parameter inversion for seismic anisotropy*
Kimberly Melissa Kumar BS Geophysics, University of Western Ontario '04	Ferguson Ent. Fall '04	MS May 2006 BP (Trinidad)	*Pore pressure prediction offshore Trinidad. BP Scholar*
Patricia Montoya BS, Geophysical Eng. Simon Bolivar, '95	Fisher/ Tatham Ent. Fall '00	MS '03/PhD May '06 ExxonMobil (Houston)	*Salt tectonics and Sequence-stratigraphic history of mini-basins near the Sigsbee Escarpment, Gulf of Mexico*
Sharon Goehring BS Geology & Computer Science Elizabeth City State University '02	Tatham Ent. Fall '03	MS Dec 2005 ConocoPhillips (Houston)	*Seismic AVO response to variations in SS reservoir properties* *Exploration Geophysics Fellowship ('03)*
Dhananjay Kumar MS Exploration Geophysics Indian Inst. of Technology (IIT) '00	Sen/ Stoffa Ent. Fall '01	PhD May 2005 Chevron (Houston)	*Analysis of multicomponent seismic data from the Hydrate Ridge, offshore Oregon*
Carmen Teresa Gomez BS Geophysical Engineering Simon Bolivar University '02	Tatham Ent. Sp. '03	MS May 2005 PhD Stanford Shell (Houston)	*Sensitivity of P-P, SH-SH and P-SV seismic reflectivity to partial gas saturation.*
Jason Andrew Stine BS, Physics Franklin & Marshall '00	Tatham Ent. Fall '00	MS May 2004 Teaching in (Baltimore)	*Sensitivity of AVO reflectivity to fluid properties in porous media*
Matthew Graham Morris BS, Geophysics U. Missouri (Rolla,) '01	Tatham Ent. Fall '01	MS Dec. 2003 Anadarko (Houston)	*Analysis on P-P and P-SV AVO response*
Chengshu Wang MS, Geology Chinese Acad. of Geol. Sci. '87	Sen/ Tatham Ent. Fall '96	PhD Aug 2003 Returned to China (PRC)	*Inversion of P-P and P-SV data, separate density effect gas hydrates. (BSR)*
Chau Ao Undergraduate NTNU (Tjåland Norway)	Tatham Ent. Fall '00	MS-NTNU May 2001 Statoil (Stavanger)	*Compare Vp/Vs interpretation between SH-SH and P-SV data.*
Fernando Cerda BS Geophysical Engineering Colorado School of Mines '96	Fisher/ Tatham Ent. Fall 'Sp. '99	MS Dec 2001 WesternGeco (Houston)	*Teal South project: Compare Vp/Vs from shear (P-SV) and interpretation with AVO results.*
Helena Zirczy BS Geophysical Engineering Simon Bolivar University '95	Tatham Ent Fall'98	MS Aug 2000 Shell (Houston)	*Multicomponent Seismic Interpretation of the Second Wind Field, Kiowa and Cheyenne Counties, Colorado*

Technical Symposia and Workshops

One of the major benefits of EDGER Forum membership is, perhaps, the "community activities" coordinated and sponsored by the Forum.

Overall, symposia and workshops have provided a platform for the exchange of ideas between industry members (contractors, equipment manufacturers and producers), academics and the graduate students. Further, the objective-oriented multicomponent seismic database is now being used by the entire technical community.

Discussions of research directions by industry and academic participants have led to student and faculty research projects. The UT-Austin EDGER Forum is in an excellent position to facilitate communication between the various elements and encourage participation of the overall exploration and development geophysics community.

User Workshops

The objective of these workshops is to share common problems, consider what kind of problems can be addressed and define focus areas among explorers, producers, contractors and manufacturers.

The first workshop, held in 2003 at the Shell facility in Houston, focused on 'Current Problems in Acquisition, Processing and Interpretation of Multicomponent Seismic Data'. Based on this, a second workshop, hosted by ConocoPhillips in Houston, was held a year later. Follow-up to these workshops was realized in an EAGE/SEG sponsored workshop in Pau, France, in 2005.

In 2009, BP hosted a well-attended one day informal workshop on Shale Plays and Unconventional Resources. The Objective of this Workshop was to share insights into geophysical observations of shales, in particular which geophysical properties of shales may differentiate between good and poor producing wells.

Industry Workshop on Shales

An Informal workshop on problems in characterization of resource shales will be held in 2013, following significant interest in a workshop originally planned for Dec 2012. The objective of this workshop will be to share and identify issues for geophysical characterization of resource shales for optimizing production. One of the outcomes of the workshop is to further identify additional research topics for student and faculty researchers supported by the EDGER Forum in relation to discussions at the annual meeting.

Short Courses

As part of technology sharing between the UT-Austin and sponsors of the EDGER Forum, faculty involved with the Forum are available for short courses. This type of contact between university and industry personnel enhances the purpose and effectiveness to the Forum.

Technical Symposia

As an element of the annual meeting, typically held on the UT-Austin campus in late February/ early March, the EDGER Forum hosts a technical symposium focused on a topic associated with problems that may be addressed through seismic analysis and modeling. These

symposia allow not only an exchange of new ideas, but also provide direction for student research projects.

Current Focus Areas of Application include unconventional resources such as resource plays, tight gas sands and shale production, time lapse seismic & reservoir monitoring as it relates to monitoring & extraction of changes in reservoir properties, and numerical simulation of seismic wave propagation, imaging and inversion. These areas have led to several joint UT / industry projects with student research theses and dissertations addressing particular issues associated with resources plays. The first symposium in December 1999 was held to ensure industry input into the reinvigorated Exploration Geophysics Initiative at UT-Austin. The symposium focused on directions for an Exploration Geophysics Program at UT-Austin, and resulted in the specification of the merged educational and research direction for the initiative and the formal proposal of the UT-Austin EDGER Forum.

As a result of industry-academic discussions, graduate student research, especially at the MS thesis level, was deemed crucial to the development of strong candidates in Geosciences, especially those with a concentration in Geophysics. The completion of a M.S. thesis was viewed as a vital element of the Geoscientist's education. This view has been consistently maintained by most industry recruiters, as opposed to a non-thesis professional M.S. Degree.

This first symposium directly led to the organization of the UT Forum for Exploration and Development Geophysics Education and Research (The UT-Austin EDGER Forum). A research focus area in the analysis, interpretation and imaging of multicomponent three dimensional seismic data was recognized as an opportunity for focusing faculty and institutional strengths. The educational aspects of the forum were a direct result of the industry input provided at this symposium. Symposia have been held every year as a part of the annual meeting of the EDGER Forum.

YEAR 13:
The Annual Meeting & Technical Symposium is scheduled for 4-6 March, 2013.

DESCRIPTION:

Seismic Characterization of Shales, Mudrocks and Tight Formation

The concentration of research activities on the characterization of shales, mudrocks and tight formations continues. With a focus on rock physics, seismic characterization and inversion for rock and fluid properties and numerical simulation of seismic wave propagation, potential applications address and expand on our understanding of the subsurface properties and production of hydrocarbons from shales, mudrocks and tight formations.

A Keynote presentation "The Next Evolution: where are we in Unconventional Geophysical Applications" by Eric von Lunen of Nexen, sets the context for presentations and discussion on seismic characterization of shales, mudrocks and tight formations.

A summary of EDGER Forum symposia (1999-Present) can be found on the next three pages.

Technical Symposia sponsored by the EDGER Forum

UT-AUSTIN EDGER FORUM	Year 13	Year 12	Year 11	Year 10
Academic Year	2012-2013 March 4-March 6, 2013	2011-2012 Feb 27-Feb 28, 2012	2010-2011 Feb 28-Mar 1, 2011	2009-2010 Feb 22-23, 2010
Topic	**Seismic Characterization of Shales, Mudrocks and Tight Formations**	**Seismic Characterization of Producing Shales**	**Seismic Characterization of Resource Shales**	**Unconventional Resources and Shale Production**
Description	The concentration of research activities on the characterization of shales, mudrocks and tight formations continues. With a focus on rock physics, seismic characterization and inversion for rock and fluid properties and numerical simulation of seismic wave propagation, potential applications address and expand on our understanding of the subsurface properties and production of hydrocarbons from shales, mudrocks and tight formations. This includes subsurface properties that may be observable in surface seismic data	In characterizing shale resources using surface seismic data, we must concentrate on the physical properties that affect seismic wave propagation. This requires an understanding of how seismically observable quantities, such as the Vp/Vs of HTI & VTI anisotropy may be related to properties, such as fracturing of kerogen content, and which quantities may effect production. Presentations and discussions include development of these relations.	Problems in shale plays are often considered completion issues until drillers find that one well came in with a two month payout and an adjacent well results in a two-year payout. Can Seismic help? Presentations examined seismic responses to variations in shale characteristics extrapolated from bore-hole log data, which was then used to test sensitivity to shale characteristics & direct analysis of shale from surface seismic.	Addressed Unconventional Resources in terms of Focus Areas of Application, including Shale Production, Time Lapse Seismic and Reservoir Characterization and Numerical Simulation and Modeling. Many of the subject numerical discussions focused on applications to shale resource plays and anisotropy effects.
Comment	A Keynote presentation "The Next Evolution: where are we in Unconventional Geophysical Applications" by Eric von Lunen of Nexen, sets the context for presentations and discussion on seismic characterization of shales, mudrocks and tight formations.	Faculty and student research utilizes borehole data, such as dipole logs and core information, to predict the seismic response to reservoir properties. This should lead to the evolution of analysis schemes to predict actual reservoir properties.	Several Students are working on cooperative projects addressing seismic issues with shale plays as very little is known about shales, and seismic response being tested from synthesis based on actual bore-hold data.	Problems are being addressed in the context of Focused Areas of Application, and this problem-orientation has been very well received by sponsors.

Technical Symposia sponsored by the EDGER Forum

UT-AUSTIN EDGER FORUM	Year 9	Year 8	Year 7	Year 6	Year 5
Academic Year	2008-2009 Feb 23-24, 2009	2007-2008 Feb 25-26, 2008	2006-2007 Feb 26-27, 2007	2005-2006 Feb 27-28, 2006	2004-2005 Feb 14-15, 2005
Topic	**How canGeophysics enhance our Search for and Definition of Unconventional Resources?**	**Seismic Methods to Address Unconventional Resources**	**Applications of P- and S-wave Methods to Land Assets**	**Seismic Response to Pore Fluid Properties**	**Seismic Response to Partial Gas Saturation**
Description	Presentations defined issues and problems associated with successful development & exploitation of Unconventional Resources. Problems discussed included silica content and Anisotropy that may be observed seismically, and the relation to productivity.	Presentations addressed issues commonly associated with exploration for and development of unconventional producing assets on land, including: tight gas sands, shale and fractured reservoirs, including the Bossier, Barnett and Bakken plays.	Presentations addressed issues commonly associated with exploration for and development of producing assets on land. This included defining strategies using the information in both P and S wave data. Interactive discussion sessions led to potential cooperative research projects.	Fluid properties considered included partial gas saturation, saturation distribution (homogenous or 'patchy'), over-pressure, and fluid viscosity. Both P- and S- wave observations will be required to fully address partial saturation issues. The program was dominated by student research results.	The program addressed defining Partial Gas Saturation and its impact on applying seismic methods to exploration and production problems. Many of the results evolved from research directions defined in the AVO symposium of 2003.
Comment	Larry Lunardi, VP Geophysics at Chesapeake Energy, presented the keynote address. Focus Areas of Application enthusiastically supported by sponsors.	Several cooperative projects with industry sponsors and UT for MS research projects.	Direct industry participation led to potential joint industry – student thesis research topics.	As with the 2005 symposium, significant student research results evolved from 2003 AVO symposium directions.	Included significant student research results evolving from directions defined in the 2003 symposium.

Technical Symposia sponsored by the EDGER Forum

	Year 4	Year 3	Year 2	Year 1	Year Zero
Academic Year	2003-2004 Feb 16-17, 2004	2002-2003 Jan 27-28, 2003	2001-2002 Jan 28-29, 2002	2000-2001 Dec 11-12, 2000	1999-2000 Dec 6-7, 1999
Topic	**Successful Applications of Multicomponent Seismic Data**	**Seismic Attributes: Deterministic and Statistical**	**New Directions in AVO**	**Geophysical Assessment of Fault and Stratagraphic Hydrocarbon Seals**	**The Future of Exploration Geophysics: Meeting the needs of Industry and Academia**
Description	Included Industry participation from a wide variety of organizations. The program focused on documented successful application of Multicomponent seismic methods in actual exploration settings.	The two-day workshop was split into one day addressing statistical attributes and one day focused on deterministic attributes. Considerable discussion centered on comparisons between the two classes of attributes, as well as specific methods of each.	Included large industry participation with a focus on New Directions in AVO applications (as opposed to improvements in AVO applications.) Provided clear research directions for student projects, including P-P and P-SV, as well as effects of fluids on seismic response.	Outlined potential research directions (identified in the 1999 symposium) for future research directions for seismically defining potential hydrocarbon seals and potential for seals. Included industry and other (outside UT-Austin) academic participation.	Program addressed what industry required from academia. Results included desire for a thesis-based MS and inclusion of seismic acquisition in the geophysical curriculum. A research focus on analysis and interpretation of multicomponent seismic data was defined.
Comment	Dr. Robert Peebler delivered the keynote address.	Topic suggested by Anadarko, one of the EDGER sponsors.	Dr. Fred Hilterman delivered the keynote address.	Dr. Peter Orteva, Indiana University, delivered the keynote address.	Dr. Tom Barron, delivered the keynote address which led to the proposal to form the EDGER FORUM at UT-Austin.

Research Activities & Cooperative Projects

The March 2013 status of student and faculty research for the current year is presented as a part of the 13th Annual Meeting of the EDGER Forum in March. Details and presentations of these results are posted on the EDGER Forum web page and are available upon request to sponsors. Included on pages 40-75 of this report are several abstracts from EDGER students and faculty to give prospective sponsors an overview of the resarch being presented at the 2013 Forum. Expanded Abstracts published by EDGER students and faculty in Volume 31 of the 82nd Annual International Meeting in Las Vegas in 2012 are included in the Interim Report. Additional submitted abstracts for other meetings are also included. Current theses, dissertations and publications are available online and upon request.

Focus Areas of Application

- **Shale Plays and Unconventional Resourses**
- **Time Lapse Seismic Analysis**
- **Numerical Simulation**

Focused Areas of Application within the context of the larger research objectives of the EDGER Forum have evolved,and been enthusiastically received by the sponsors. Cooperative projects with sponsors continue to be a fruitful area of collaboration, particularly when these include specific resource plays.

These evolving aspects include seismic responses to variations in resource (gas and oil) shales, time-lapse seismic and reservoir monitoring and numerical simulation (and inversion) of seismic wave propagation processes. Full elastic, and multicomponent, considerations are essential to fully address these challenging applications.

Graduate students with a focus on Exploration Geophysics are included in the student summary table on pages 16-17. Brief comments on the research project of each student or alumnus are included. Faculty and post-doctoral research topics are included in the personnel section on page 36. At the present time, five masters students are working on thesis topics coordinated with industry sponsors, including internships and data sets from the partners. The EDGER Forum is a crucial aspect of our graduate student support, as well as the overall research program. For year thirteen to date EDGER Forum graduates and faculty have completed 35 publications.

Faculty Expertise

Research projects are organized into broad subject areas and championed by the Co-PI's as follows:

- **Analysis of Interprtation of Multicomponent Seismic Data (Tatham)**
- **Imaging Seismic Data in Complex Media (Sen/ Stoffa)**
- **Modeling / Inversion of Seismic Data including Anisotropy (Sen)**
- **Numerical Simulation of Geophysical Processes (Stoffa)**
- **Rock Physics and Inversion of Seismic Data for Rock Properties (Spikes)**
- **Numerical Wave Propagation in Realistic Media (Spikes)**

The following is a small example of faculty and graduate research from EDGER Year 13, as well as current student projects involving the Forum's industry partners.

Meijuan Jiang entered JSG as a PhD student in 2010. She characterizes the reservoir properties (porosity, composition and pore shape) for the Haynesville Shale. She uses rock physics models that provide relationships among elastic properties and the reservoir properties to build effective shales, considering multiple mineral/pore/crack/fracture phases and anisotropy. She matches the modeled P- and S-wave velocities to measured or inverted velocities and applies grid searching to obtain estimates of the reservoir properties. To date, she estimated porosity and composition at well locations. The pore shape estimation must be compared with the microstructure images from core data. She will obtain continuous distributions of these reservoir properties by applying the procedure at the seismic scale.

Patrick Gustie is a first year MS student interested in exploring the amplitude variation with offset response of a nine component synthetic seismic model in a transversely isotropic medium. He also intends to model the response of a cracked medium with crack orientation varying with azimuth. He plans to test the applicability of these models with real 3C or 9C data for different rock properties using appropriate models.

Qi Ren is a first year Ph.D student. She is currently working on the anisotropy of Haynesville Shale with lab measurements and Eagle Ford Shale modeling with well log data. She will move on to Haynesville rock properties, using both seismic and well log data supplied by EDGER Forum members. She will model the Haynesville Shale reservoir properties, including composition, fluid saturation and anisotropy.

Karl Oskar Sletten is a visiting MSc student from NTNU, Norway. He has been working on modeling of the 4D seismic response obtained from fluid flow simulations at the Norne field. Future work might also include estimation of changes in pressure and fluid saturation through rock physics and seismic inversion.

Sharif Morshed is a M.S. student working on seismic characterization of the Marcellus Shale. He will graduate in Spring 2013. His research involves anisotropic seismic modeling and rock physics modeling. He used different effective medium theories particularly the anisotropic differential effective medium theory, for modeling the organic shale. He conducted VTI and HTI seismic modeling to investigate the seismic response in the productive zone of the Marcellus Shale.

Lauren Becker is currently a first year MS student. She is continuing research begun last spring to identify changes in subsurface fracture orientation, geometry, and fill through the study of seismic attributes. She is using a finite element numerical wave propagation model for fractured media with individual fills and fracture forms. From the model, seismic attenuation and wavefield scattering patterns are obtained and used to identify the presence of and characterize complex fracture networks.

Russell Carter is currently a third year PhD student. His work involves characterizing and monitoring injected CO_2 in the Cranfield reservoir. His

research involves integration of rock physics, well-logs, 3D and time-lapse vertical seismic profiles, and time-lapse surface seismic data. The project goal is to use statistical rock physics and seismic data to characterize the lateral extent and spread of injected CO_2. Recent developments include a probabilistic joint inversion of the contact cement model for porosity and fluid saturation at a monitoring well. Future work will involve expanding the joint inversion so that the input data comes from surface seismic data and the 3D vertical seismic profile to help generate probabilistic porosity and fluid saturation volumes for the entire reservoir.

Mohammed Alhussain is a fourth year PhD student. His research title is Fracture Characterization of a Carbonate Reservoir in the Arabian Peninsula. His goal is to develop new techniques for seismic characterization of a fractured reservoir with the goal of investigating applicability to a carbonate reservoir in the Arabian Peninsula. His work involves integration of well logs and 3D seismic data.

Yang Xue is currently a fourth year PhD student working on novel stochastic inversion methods for reservoir characterization and reservoir monitoring. She has developed a new stochastic inversion method, called Greedy Annealed Importance Sampling (GAIS), for an efficient and accurate estimation of both elastic properties and their uncertainties. She applied this method to both trace-by-trace seismic inversion of post- and pre-stack data and simultaneous inversion along 2D lines.

Kumar Sundaram Das is an MS student looking to graduate summer of 2013. His research is the quantification of gas hydrates in the Krishna-Godavari basin, India, using seismic inversion and multi-attribute analysis. His research was carried out at the National Geophysical Research Institute, India.

Makoto Sadahiro is a first year MS student implementing a 3-D Fourier Transform to address large-scale Reverse Time Migration (RTM). The motivation is to optimize computational effeciency of RTM on a cluster of Graphic Processing Units (GPU).

Jacqueline Maleski is a first year Master's student. Her research involves AVO induced direct shear wave polarization distortion. She will use successive layer stripping to remove polarization distortion in the presence of depth variant anisotropy. 9C-3D seismic data from the Vacuum Field in New Mexico should provide an ideal case to study the efficacy of these techniquess

Han Liu is a PhD student who joined JSG in Fall 2012. Han's research topic is finite element simulation of wave propagation in complex media. The aim of this research is to provide improved estimation of elastic properties of rocks having a distribution of complex geometrical shapes and types of fluid fills. She will build several digital rock models of fractured media with different shapes and then more accurate velocity will be estimated after simulated hydraulic fracturing.

Sarah Coyle is a first year MS student. Her research involves investigating the effectiveness of the use of rock-typing for improved inversion results in the Haynesville Shale. The project goal is to improve the ability to identify sweet spots for horizontal drilling and hydraulic fracturing programs in unconventional shale gas reservoirs.

Jiao Xue is a visiting PhD student from China University of Geosciences. Her research is about reservoir characterization, including anisotropy parameter estimation and inversion for saturated, fractured and porous reservoirs. She is currently working on characterization of and general fracture weakness for saturated, fractured and porous rock expressed by elastic constants of the host rock, fracture parameters for dry rocks, and fluid parameters.

Research Directions

To summarize current research aspects of our objectives, the research focus of the EDGER Forum has been analysis, imaging and interpretation of multicomponent seismic data, including P-P and P-SV AVO. This includes development of seismic inversion algorithms and rock-physics analyses to provide an integrated suite of seismic data analysis tools. These three related aspects are being applied to shale characterization as well as to geophysical descriptions of conventional reservoirs for both fluid extraction and fluid storage.

Professor Tatham and his students are currently working on seismic analyses of the Woodford and Marcellus Shales specifically variation in Poisson's ratio and anisotropy parameters within the shales. Additional projects include polarization corrections for SV- and SH-waves in isotropic and anisotropic media.

Professor Spikes and his students continue to link quantitatively pore-scale reservoir characteristics to larger scale geophysical measurements. The emphasis is primarily on unconventional reservoirs, the Bakken and Haynesville Shale in particular. Additional work is being done to understand the effects of CO2 on seismic responses for EOR and CCUS technologies. Finally, comparisons are being made between numerical wave propagation and effective medium models to assess the viability of both for use in quantitative interpretation.

Professor Sen and his students and post docs continue to work on a wide range of topics. These include wave-propagation modeling, inversion-based reservoir characterization for conventional and fractured reservoirs, and rock models for various reservoir types.

Professor Stoffa will be working more closely with the EDGER Forum and will be advising students in the area of numerical simulation of seismic wave propagation in elastic media. Several projects with students in both the Computational and Applied Math and Post-Doc researchers were included in the annual meeting presentations. The opportunity to interact with the Texas Advanced Computing Center (TACC), located in a building shared by the UT Institute for Geophysics on the J. J. Pickle Research campus, enhances likelihood of success in this endeavor. Both the Lone Star and Ranger 'supercomputers' are part of TACC.

The emphasis in recent years, both within the EDGER forum and in the industry as a whole, suggests potential partnerships between UT and interested parties from the Forum. This would provide opportunities to transfer and share technological advancements between industry and academia.

For the past several years, our annual technical symposium has focused on land assets and unconventional resources, whereas the earlier symposia of the EDGER forum focused on seismic characterization of seals. We envision a practise of using seismic methods to look at shales, which can be a source, seal and/or reservoir. Several students are focusing on the seismic response to resource shales. Modeling parameters are derived from borehole log data, including dipole sonic or sonic scanner log data, and relation to actual productivity are largely hypothesized from anecdotal information. As available productivity information independent of completion techniques applied and the strategies of drilling programs are realized, seismic observations are expected to play a more significant role in drilling and completion decisions. Faculty, student and post-doctoral research will likely continue in this area for the foreseeable future.

Within the context of the larger research objectives of the EDGER Forum, these Focus Areas of Application have been enthusiastically received by the sponsors.

At the present time, the area of application addressing seismic characterization of unconventional resources, including resource plays, tight gas sands and shale production has emerged. This application area also dominated the topics of recent annual technical symposia. It has led to several cooperative UT / industry projects with student research theses and dissertations addressing particular issues associated with resources plays. Working collaboratively with our industry partners, cooperative projects, along with industry internships (over 50 to date) are instrumental in developing graduate students thesis topics and have been very well received by sponsors. Industry internships and cooperative projects help accomplish many of the objectives of the professional MS students to graduate with a full thesis and research experience.

A number of specific cooperative projects during EDGER Year 12 & 13 have evolved around the focus area addressing seismic characterization of unconventional resources. These projects were discussed as part of the last annual meeting with members of the Forum helping to define research directions. Projects to date are outlined below and new developments are being formed with students to include projects in the Woodford, Barnett and Marcellus Shales (as well as other reservoir plays) and deep-water objectives. Students gain firsthand experience with companies on actual exploration and development projects, and are well prepared to enter the industry.

Progress reports of current cooperative projects are discussed at the Annual Meeting & Technical Symposium. The annual events aim to benefit all participants through the exchange of information. Presentations are made by Faculty, PhD and MS students and post-doctoral researchers at the annual meeting.

Cooperative Projects

Focus Area of Application	Project	Student/Faculty	Partner
Unconventional Resources	Woodford Shale	Alexander Lamb (MS 2012)	Devon / Cimarex
	Haynesville	Kwon Taek Oh (MS 2012)	BP
		Meijuan Jiang	
		Qi Ren	Chevron
		Sarah Coyle	
	Marcellus Shale	Sharif Morshed	Anadarko
	Fracture Modeling	Lauren Becker	Evolving
	Elastic Deformation	Han Liu	Evolving
Time Lapse Seismic and Reservoir Monitoring	Cranfield Carbon Sequestration Project	Russell Carter	Gulf Coast Carbon Center (BEG)
		Rui Zhang	Evolving with support from DOE & the Center for Subsurface Energy Security
Inversion of Seismic	Stochastic Inversion	Yang Xue	Shell

Relevant Publications (2012 - 2013)

Alhussain, M., and M. K. Sen, 2012, Removing anisotropic overburden effect for reliable reservoir fracture characterization, 82nd Annual International Meeting, SEG, Expanded Abstracts, 1-5.

AlMuhaidib, Abdulaziz, M. K. Sen, and M. Nafi Toksoz, 2012, Integration of geology, rock physics, logs and pre-stack seismic for reservoir porosity estimation, AAPG Bulletin, 96, 1235-1251

Campbell, T. & Tatham, R. H., 2013, Rotation of Shear-Wave Components at Non-Normal Angles of Incidence, Accepted for the 75th EAGE Conference & Exhibition incorporating SPE EUROPEC, London June 2013

Campbell, T. & Tatham, R. H., 2012, Corrections for polarization distortion in reflected shear waves and possible extensions to the Alford rotation at non-normal incidence angles and applications, Expanded Abstracts, Vol. 31, 82nd Annual International Meeting, Society of Exploration Geophysicists, 31, MS E-P1-1.8

Carter, R. W., and K. T. Spikes, 2013, Sensitivity analysis of Tuscaloosa Sandstones to CO2 saturation, Cranfield Field, Cranfield, MS: International Journal of Greenhouse Gas Control, in press

Carter, R. and K. T. Spikes, 2012, Modeling fluid composition in CO2-saturated sandstone using a statistical rock physics approach, Cranfield Field, Cranfield, MS, Abstract MR33A-2429 presented at 2012 Fall Meeting, AGU, San Francisco, Calif., 3-7 Dec.

Ghosh, R., and M. K. Sen, 2012 Predicting subsurface CO2 movement: from laboratory to field scale, Geophysics,77(3), M27–M37

Jiang, M. and K. T. Spikes, 2012, Characterizing the reservoir properties of the Haynesville Shale using rock-physics modeling and a grid search method: Geophysical Journal International, in review.

Jiang, M. and K. T. Spikes, 2012, Estimation of the porosity an pore aspect ratio of the Haynesville Shale using the self-consistent model and a grid search method, Expanded Abstracts of the 82nd Annual Meeting of the SEG, 31, http://dx.doi.org/10.1190/segam2012-0134.1

Kongrath, S., R. H. Tatham, & K. T. Spikes, 2012, Comparison of Fluid Prediction Success between AVO and Bright Spot Techniques in the Marco Polo Field, The Gulf of Mexico, International Petroleum Technology Conference, Bangkok, Feb. 2012. IPTC 14573

Liu, T., M. K. Sen, T. Hu, and J. D. DeBasabe, 2012, Dispersion analysis of the spectral element method using a triangular mesh, Wave Motion, Wave Motion, Volume 49, Issue 4, June 2012, Pages 474-483

Liu, Y. and M. K. Sen, 2012, Time-space domain dispersion relation based finite-difference method with arbitrary even-order accuracy for the 2D acoustic wave equation, Journal of Computational Physics, http://dx.doi.org/j.jcp.2012.08.025.

Liu, Yang and M. K. Sen, 2012, A hybrid absorbing boundary condition for elastic staggered grid modeling, Geophysical Prospecting, DOI: 10.1111/j.1365-2478.2011.01051.x.

Martinsen, O. J., M. Talwani, C. Dengo, B. Barkhouse, J.F. Dunn, A. Levander, C. Link, S. Mosher, J. Orcutt, D. Paul, R. Talley, R. H. Tatham, 2012, A U.S. human resource challenge for Earth science education and energy exploration and exploitation, The Leading Edge, v31, no6, June 2012

Moyano, B., K. T. Spikes, T. A. Johansen, N. H. Mondol, 2012, Modeling compaction effects on the elastic properties of clay-water composites: Geophysics, 77, 5, 1–13, DOI: 10.1190/GEO2011-0426.1

Oh, K. T. and K. T. Spikes, 2012, Velocity modeling to determine pore aspect ratios of the Haynesville Shale, Expanded Abstracts of the 82nd Annual Meeting of the SEG, 31, http://dx.doi.org/10.1190/segam2012-0508.1

Relevant Publications (2012 - 2013)

Saraswat, P. and M. K. Sen, 2012, Artifical neural systems based self organizing maps for seismic facies analysis, Geophysics July 2012 v. 77 no. 4 p. O45-O53

Saraswat, P. and M. K. Sen, 2012, Pre-stack inversion of angle gathers using hybrid evolutionary algorithm, Journal of Seismic Exploration, Vol 21, No. 2, May 2012

Sen, M. K., and P. L. Stoffa, 2013, Global Optimization Methods is Geophysical Inversion, Second Edition, Cambridge University Press, In Press

Shahin, A. and K. Kerry, P. L. Stoffa, R. H. Tatham, 2012, Petro-electric modeling for CSEM reservoir characterization and monitoring, Geophysics, January 2012, v. 77, p. E9-E20, doi:10.1190/geo2010-0329.1

Shahin, A., P. L. Stoffa, R. H. Tatham, R. K. Seif, 2012, Time-lapse seismic modelling: Accuracy required to detect signals from a water flooded reservoir, J. Seismic Explor., 21, 49-82, 2012

Spikes, K. T., 2012, Overview of rock property relationships and characterization methods for selected oil and gas shales in North America: Geohorizons, January Issue

Spikes, K. T. and Jiang, M., 2013, Rock physics relationships between elastic and reservoir properties in the Haynesville Shale: AAPG Memoir, in press.

Spikes, K. T., 2013, Error estimation of VTI behavior in shale, in preparation.

Stewart, R., K. T. Spikes, J. Sisson, S. Hall, J. Huang, and S. Danbom, 2012, Outstanding in the field: Hands-on geophysical education: The Leading Edge, 31, 3, 278–284

Tao, Y., and M. K. Sen, 2013, Frequency domain full waveform inversion with plane wave data, Geophysics, VOL. 78, NO. 1 (JANUARY-FEBRUARY 2013); P. R13–R23.

Tao, Y., M. K. Sen, R. Zhang, and K. T. Spikes, 2013, A robust stochastic inversion workflow for time-lapse data: hybrid starting model and double-difference inversion, in review

Tao, Y., and M. K. Sen, 2012, Subtracting non-Gaussian noise in reverse time migration, Geophysical Prospecting, In Press.

Tao, L., T. Hu, M. K. Sen, J. Yang, R. Wang, J. Wei, 2012. A hybrid scheme for seismic modeling based on Galerkin method, Geophysical Journal International, doi: 10.1111/j.1365-246X.2011.05094.x

Tatham, R. H. and A. M. Perez, 2012, Azimuthal effects of structural dip and CMP bin size on reflection travel times, EAGE 74th Annual Conference and Exhibition, Copenhagen (X032)

Tatham, R. H. and P. M. Krail, 2012, Physical Insight into the Elastic Brewster's Angle, EAGE 74th Annual Conference and Exhibition, Copenhagen (CO17)

Tatham, R. H. and P. M. Krail, 2012, Zero crossings, the elastic Brewster's angle and physical insight into shear-wave reflections, Vol. 31, 82nd Annual International Meeting, Society of Exploration Geophysicists, 31, MS E-P1.7,

Tatham, R. H., 2012, Invited paper-Seismic Applications in the Exploration for and Development and Production of Unconventional Hydrocarbon Resources (An overview), Geohorizons, 17, 1 5-17.

Zhang, R., M. K. Sen, and S. Srinivasan, 2013, Pre-stack basis pursuit inversion, Geophysics, VOL. 78, NO. 1 (JANUARY-FEBRUARY 2013); P. R1–R11.

Zhang, R., M. K. Sen, S.Phan, and S. Srinivasan, 2012, Stochastic and deterministic seismic inversion methods for thin-bed resolution, Journal of Geophysics and Engineering, October 2012, v. 9, p. 611-618, doi:10.1088/1742-2132/9/5/61

Sponsorship and Funding

Corporate participants are asked to sponsor the Forum at an annual rate of $40,000 per year. Although organized and administered similar to traditional university research consortia, this Forum for Exploration and Development Geophysics Education and Research also focuses on a total education program.

The Forum also provides a process and platform for directing industry input into the educational and research activities as well as cooperative projects between sponsors and the University of Texas-Austin.

As an academic partner, the EDGER Forum is capable of organizing projects—such as topical workshops—for the exclusive benefit of all members and there are opportunities for additional cooperative projects in the EDGER Forum and sponsor input is most welcome.

The proposed funding is highly leveraged with other sources of funds specifically for student support and will further support educational aspects of the program as well as focused research areas such as characterization of resource shales. Thus, EDGER Forum dues supplement increased educational support from the Dept. of Geological Sciences, the Jackson School of Geosciences and the UT-Austin Geology Foundation. Cooperative efforts continue between all units of the Jackson School, including the UT Institute of Geophysics and the Bureau of Economic Geology.

Student support is a critical element of this program and as a guide, the cost associated with an individual PhD student are illustrated below. EDGER funding is supplemented through other sources of funding supporting the Exploration Geophysics Initiative, so each member's contribution in combination with additional support provided through research grants as well as the UT Geology Foundation helps achieve a larger educational objective.

Membership is renewable annually with a general renewal date of May 31st to coincide with graduate student participation in summer research projects. Active research efforts will commence in June, and continue with faculty participation until the fall academic term, when students will continue their participation. Other renewal dates may be recognized for individual participants who desire a specific annual cycle.

Typical cost to support a PhD graduate student at UT in 2012-2013	
Gradute Research Assistant (Summer/Spring/Fall GRA Stipend)	$ 24,407
Fringe Benefits (Health Insurance, etc...)	$ 6,590
Tuition & Fees* (Not subject to UT overhead)	$ 13,088
Incidentals (travel, workshops, thesis copying, etc.)	$ 5,000
UT Overhead (approx. 50%)	$ 24,542
TOTAL Cost per student	**$ 73,627**

**tuition not subject to overhead*

Budget

An income of $380,000 in annual membership fees was received during the 2012/13 term. Assuming thirteen industry participants commit at $40,000 in the next term, the Forum's budget will be $520,000 for June 2013 - May 2014 term.

Furthermore, in 2012 the EDGER Forum established an account with the University's Office of Industry Engagement in the Office of Sponsored Projects. With this industry engagement account EDGER sponsors agree to the terms of the Industrial Affiliates Program (IAP). With this agreement in place funding is not subject to the University overhead costs (50%) usually associated with sponsored research.

In the current year, 60% of sponsorship funding is committed to direct support of research activities including MS and PhD student research, stipends and a partial contribution to summer support by faculty. With additional commitments, the next term will include support for a full-time post-doctoral researcher and bring the direct student educational and research support to 75%. In its simplest terms, the anticipated budget for funds generated by the 'Geophysical Forum' will be:

1. **Direct Student & Post-Doc Educational and Research Support (~76%).**
2. **Staff costs including Program Coordinator, Technical and Administrative Support (~17%)**
3. **Costs associated with Annual Events, Reports, Workshops and overall operational expenses (~4%)**
4. **Contingency (~3%)**

EDGER Forum Budget		**Actual/Encumbered to 31st May 2013 EDGER YEAR 13 (June 2012 - May 2013)**		**Proposed for June 2013 - May 2014 EDGER YEAR 14 (June 2013 - May 2014)**	
		(Ten Sponsors)		**(Thirteen Sponsors)**	
PROGRAM					
Operations, Workshops & Annual Forum Events	**Meetings, Reports & MOE**	**$ 17,977**	5%	$ 20,000	4%
	Subtotal: Program Support (5%)	**$ 17,977**	**5%**	**$ 20,000**	**4%**
RESEARCH					
Graduate Research Assistant (GRA) Stipends	**Student GRA Salaries (3 terms: June-May)**	**$ 104,882**	28%	**$ 126,110**	24%
Post-Doc Research Salary	**Post-Doc Research Salary**	**$ -**	0%	**$ 65,000**	13%
Partial Contribution for Summer Faculty Research	**Partial Faculty Summer Salaries**	**$ 23,721**	6%	**$ 40,222**	8%
	Fringe Benefits	**$ 34,723**	9%	**$ 62,460**	12%
	Tuition	**$ 54,138**	14%	**$ 85,770**	16%
	Student Contingency Fund	**$ 12,000**	3%	**$ 16,000**	3%
	Subtotal: EDGER Research (60%)	**$ 229,464**	**60%**	**$ 395,562**	**76%**
STAFF Forum Coordinator, Admin and Technical Support					
	Applications Support	**$ 15,938**	4%	**$ 15,938**	3%
	Forum Coordinator/Administrative Support	**$ 45,900**	12%	**$ 52,000**	10%
	Fringe Benefits	**$ 16,696**	4%	**$ 18,343**	4%
	Subtotal: Staff Support (21%)	**$ 78,534**	**21%**	**$ 86,281**	**17%**
TOTALS	**Expenditure (86%)**	**$ 325,975**	**86%**	**$ 501,843**	**97%**
	Reserve (14%)	$ 54,025	14%	$ 18,157	3%
	Income (100%)	**$ 380,000**	**100%**	**$ 520,000**	**100%**

Personnel

Robert H. Tatham
Dr. Tatham is a Professor for the Department of Geological Sciences and holds the Shell Companies Foundation Centennial Chair in Geophysics. He joined the faculty in 1999 and has more than 30 years' experience both in the contracting and major production segments of the industry. He is Principal Investigator for the EDGER Forum.

Mrinal K. Sen
Dr. Sen is a Professor for the Department of Geological Sciences and UTIG. He holds the Jackson Chair in Applied Seismology and is the current Director of the National Geophysical Research Institute (NGRI). He advises graduate students in all areas of Geophysics and applied mathematics at UTIG, where he has been a researcher since 1989. He is Co-Principal Investigator for the EDGER Forum.

Kyle T. Spikes
Dr. Spikes joined the Faculty in 2009 as an Assistant Professor with a focus in rock physics. He completed his PhD at Stanford University in 2008. Before arriving at UT-Austin, Dr. Spikes was a Post-Doctoral Fellow at the University of Bergen in Norway. He is Co- Principal Investigator for the EDGER Forum.

Paul L. Stoffa
Dr. Stoffa is a Professor for the Department of Geological Sciences and holds the Shell Distinguished Chair in Geophysics. He was Director of UTIG from 1994-2008. He actively advises graduate students supported by the EDGER Forum and working on sponsored research.

Margo C. Grace
Ms. Grace is the Project Coordinator for the EDGER Forum and is responsible for organizing, developing and promoting events including workshops, symposia and meetings. She maintains websites and databases and develops member services as well as overseeing the budget, sponsor contracts and the financial status of EDGER Forum funds.

Thomas E. Hess
Mr. Hess provides crucial technical support for the EDGER Forum's research efforts as Seismic Applications Software Manager. He oversees seismic data sets from our sponsors and supports graduate students, faculty and researchers for the Exploration Geophysics program in the Dept. of Geological Sciences as well as for the UT Institute for Geophysics.

Jiancong Xiong
Jiancong Xiong, Senior Engineer at Sinopec, will be working with the EDGER team in 2013-2014 as a visiting scientist. Xiong will conduct research into seismic anisotropic properties pertaining to the characterization of shale resources. Results of this research will lead to methodologies, which will provide guidance to the both exploration and production of shale resources.

Other faculty and researchers
Faculty and research scientists from all three branches of the Jackson School of Geosciences, the Dept. of Petroleum & Geosystems Engineering, and the Texas Institute for Computational and Applied Mathematics continue to participate in various activities of the EDGER Forum and support graduate students with a focus in exploration geophysics

Special Thanks to All our Sponsors!

EDGER ABSTRACTS

2013 EDGER Forum Annual Meeting & Technical Symposium

EDGER ABSTRACTS

2013 EDGER Forum Annual Meeting & Technical Symposium

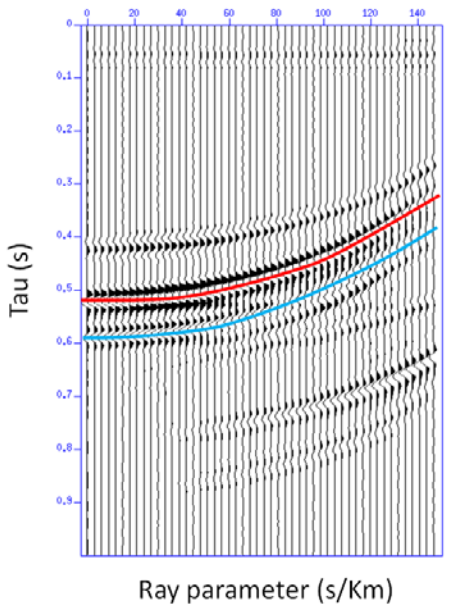
ESTIMATION OF FRACTURE PARAMETERS AFTER REMOVING ANISOTROPIC OVERBURDEN EFFECT

Mohammed Alhussain and Mrinal K. Sen

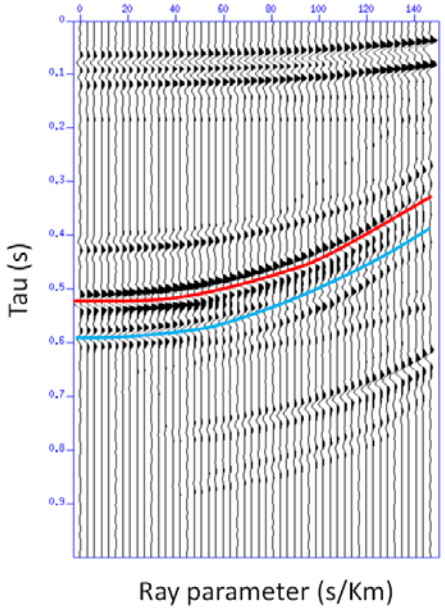
Department of Geological Sciences
The University of Texas at Austin

ABSTRACT

Estimation of reservoir fracture parameters such as fracture orientation and density or fracture normal and tangential weakness (ΔN and ΔT respectively) from seismic data is often difficult because of one important question: Is the anisotropy caused by the reservoir interval alone or by the effect of the lithologic unit above the reservoir? Often hydrocarbon reservoirs represent a small portion of the seismic section and inversion of reservoir anisotropic parameters can be easily obscured by the presence of anisotropic overburden. In this paper, we show examples where we can clearly observe imprints of overburden anisotropic layers on the seismic response of the target zone. Then we present a simple method to remove the effect of anisotropic overburden to recover reservoir fracture parameters. It involves analyzing amplitude variation with offset and azimuth (AVOA) for the top of reservoir reflection amplitude and for a reflector below the reservoir. Seismic gathers are transformed to delay-time slowness (tau-p) domain. We then calculate the ratio of the amplitudes picked at the reservoir top and for the reflector beneath the reservoir. The ratio is then used to remove the transmission effect of the overburden. The methodology is applied to two sets of models: one containing a fractured reservoir with isotropic overburden and the other containing a fractured reservoir with anisotropic overburden. Conventional analysis in the x-t domain indicates that the anisotropic overburden has completely obscured the anisotropic signature of the reservoir zone. When the new methodology is applied, the overburden effect is significantly reduced. Inversion of fracture parameters is applied to both conventional AVOA curves and the new amplitude ratio attribute. We show that the fracture parameter ΔN is estimated accurately whereas ΔT parameter is not stable and could not be recovered using only P-to-P reflection data.



(a)



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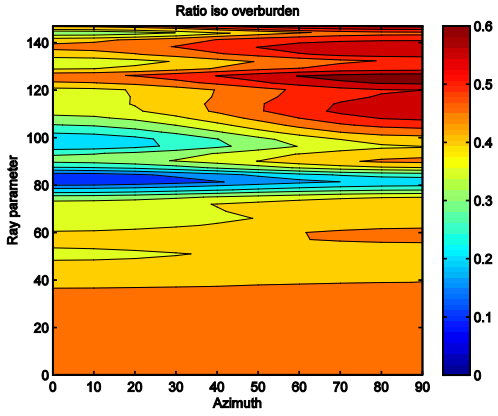

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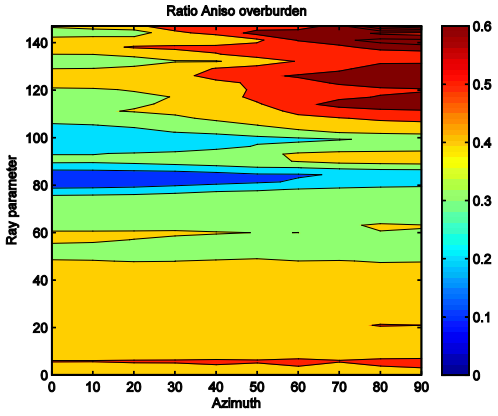

(d)

Transformed CDP gathers in the tau-p domain of two models - one containing a fractured reservoir with isotropic overburden (a) and the other containing a fractured reservoir with anisotropic overburden (b). The new introduced method involves analyzing amplitudes in the tau-p domain for the top of reservoir reflection amplitude and for a reflector below the reservoir (red and blow lines in (a) and (b) respectively). We then calculate the ratio of the amplitudes of both horizons. The ratio is then used to remove the transmission effect of the overburden. The amplitudes ratios for both models are shown in (c) and (d). They have almost the same amplitude ratio values where overburden effect is believed to be removed.

ANALYSIS OF FRACTURE-RELATED SEISMIC ATTENUATION AND SCATTERING: INSIGHTS GAINED THROUGH NUMERICAL MODELING

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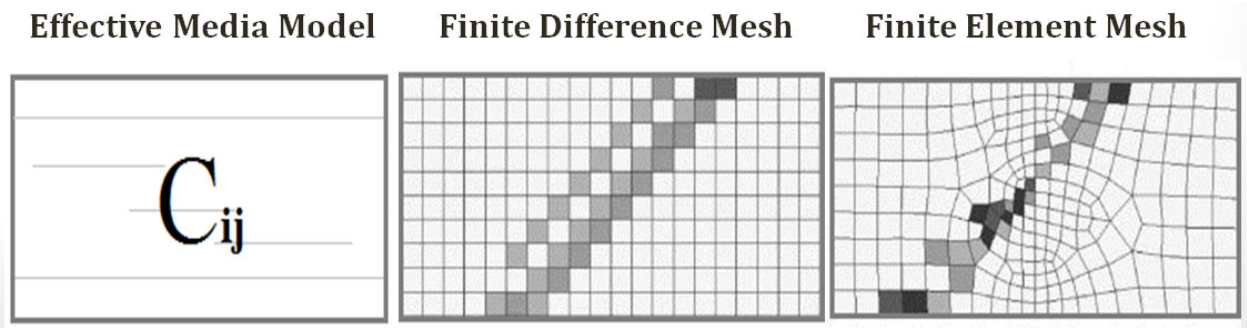
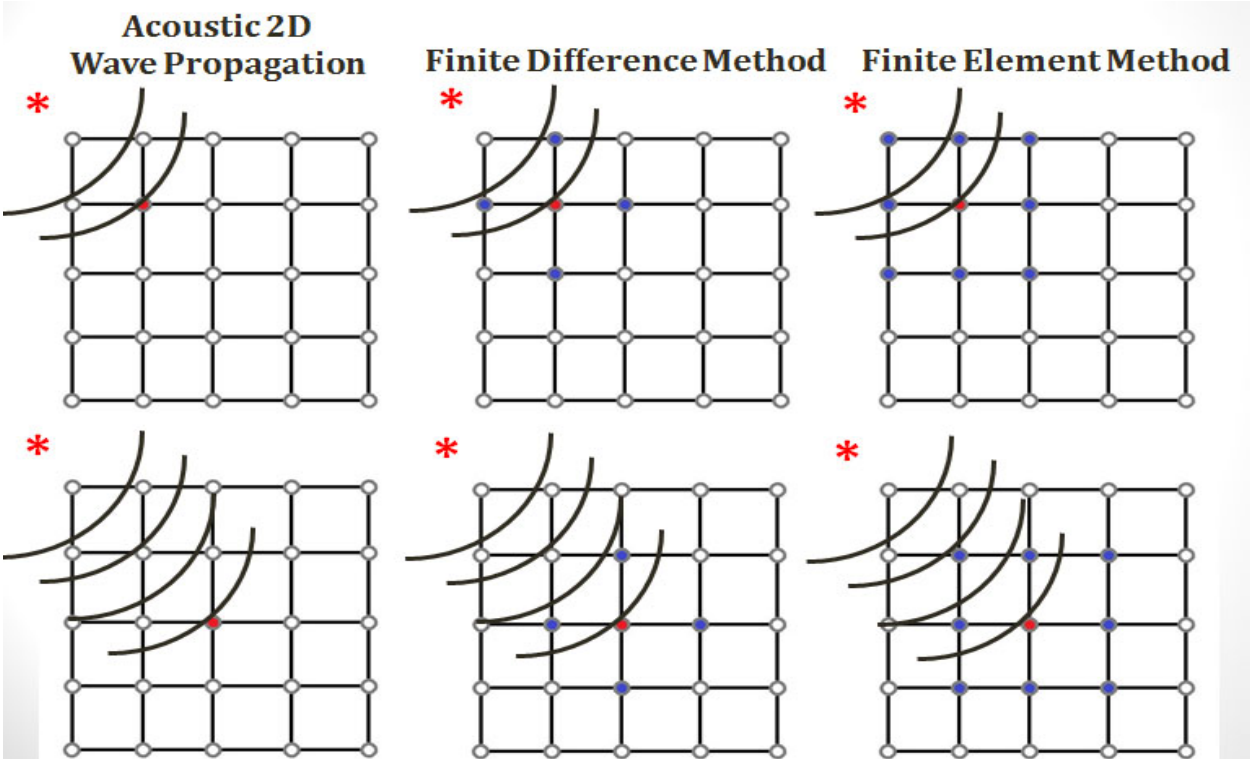
ABSTRACT

The orientation, geometry, and fill attributes of subsurface fracture networks can be characterized by seismic surveying through the study of seismic energy attenuation, wavefield scattering, and directional phase velocities. This method of understanding in-situ reservoir features is an indirect approach, however, and requires an in-depth understanding of the seismic response to each property and how the signatures of these properties combine to form seismic observations. To understand any characteristics of a fracture network, a model must be implemented to accurately represent the subsurface and predict the outcome of changes in individual fracture attributes. Previous studies using finite difference modeling techniques have correlated these properties to differing patterns in energy attenuation and scattering for transversely isotropic media. For more complex systems, such as orthorhombic symmetry or heterogeneous fracture clustering, this modeling technique is greatly limited in its ability to discern fracture parameters due to extensive wavefield interference and cancellation. To advance this study, I propose the use of finite element wave propagation techniques that offer more freedom to modeling parameters. This freedom allows for better contouring of the discontinuous fracture interface and, therefore, can more accurately represent the reflections and diffractions from these surfaces. Through the application of this better suited method of modeling, I will be able to more accurately identify the presence of and characterize complex fracture networks. This study is, however, still in the development stage of model validation. By first repeating the work of a finite difference study, I will be able quantify the superiority or inferiority of finite element methods over finite difference methods and then continue on to model implementation.

#1 Modeling Techniques: **a)** **b)**



#2 Wave Propagation Techniques: **c)** **d)**



A comparison of the differences between finite element and finite difference modeling methods 1) and wave propagation methods 1) is shown. The main modeling methods (1) for representing fractures are effective media models that average fracture attributes in each layer to compute the compliance tensor S_{ij}, discrete fracture finite difference models that compute the normal and tangential compliance in each of the uniform grids (a), and discrete fracture finite element models that compute the normal and tangential compliance in each unstructured grid (b). The main methods for solving the elastic wave partial differential equation (2) in a discontinuous media are finite difference methods that approximate the derivatives with Taylor series expansions, which only require five adjacent nodes for accurate calculation in an acoustic 2D case (c) and finite element methods that use the weak form of the elastic wave equation to solve the derivatives, which require nine nodes for accurate calculation in an acoustic 2D case (d). Note that in both cases the number of nodes required exponentially increases with added dimensions and complexity, as in an elastic case.

ROTATION OF SHEAR-WAVE COMPONENTS AT NON-NORMAL ANGLES OF INCIDENCE: BLACK-BEAR DATA, OKLAHOMA

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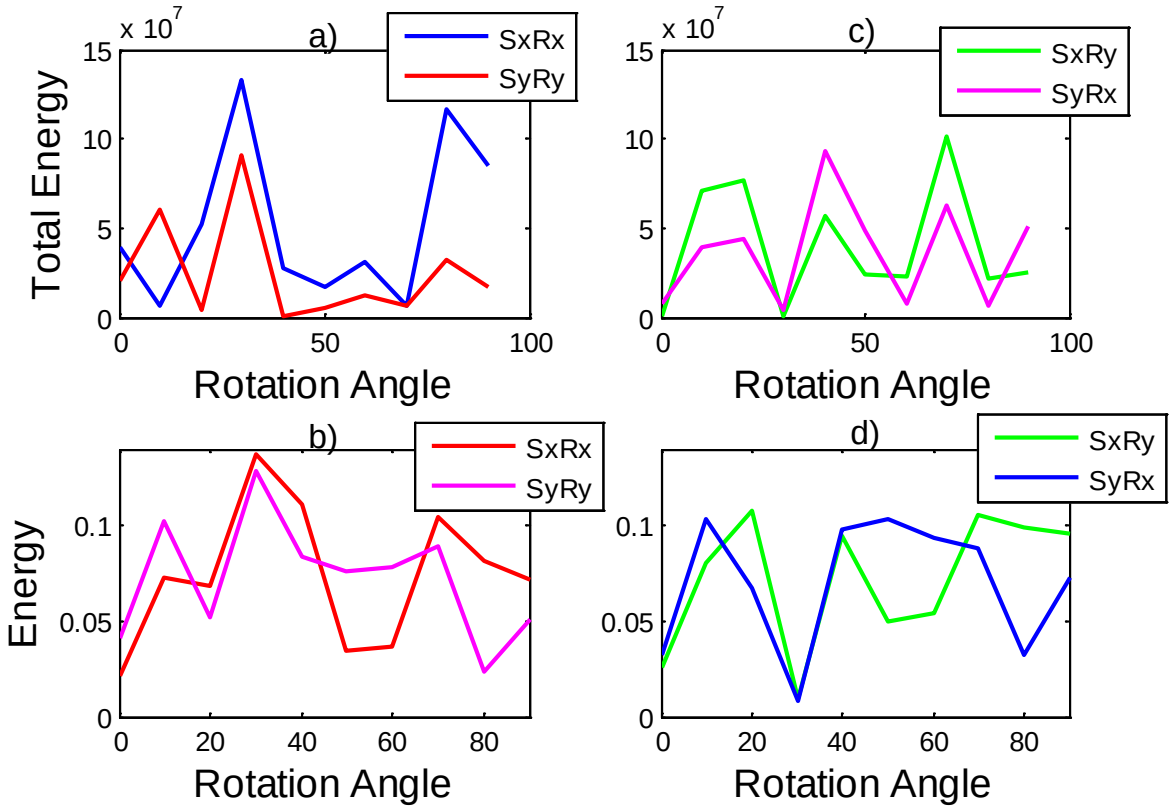
ABSTRACT

Analysis of seismic shear wave information is useful in characterizing properties of the media they travel through. Alford (1986) introduced a method of rotating combinations of observed seismic traces from orthogonal pairs of shear-source and shear-receiver components to identify the azimuthal orientations of symmetry axes of birefringence. This method has been widely applied to interpretation of subsurface fracture properties. As currently applied, this analysis is limited to zero-offset reflections, which results because the normal incidence reflection response is identical for SV and SH reflectivity. For non-normal incidence angles, however, there is a pronounced difference in SV and SH reflectivity as source-receiver offsets increase, leading to significant distortion in the polarity of the reflected shear wave. Polarization distortion due to the reflection process in typical 3D acquisition geometry is demonstrated and a correction to the polarization distortion is presented. The only information required for the correction is the angles of SV and SH zero crossings, typically at angles near 20° for SV and 40° for SH for most sedimentary rocks. This correction can be applied to the four horizontal components of 9C direct shear data at non-zero source-receiver offsets. The application of this 'corrected' analysis leads to an extension of the widely applied Alford rotation method to a wide range of reflection angles of incidence, and inclusion of a wide range of source-receiver offsets in pre-stack data. Examples of this analysis are given for both synthetic and field (Black Bear, Oklahoma) data.



Results of the proposed Alford-like rotation polarization scan applied to horizontal components of 9C shear synthetic models (a) and (b)—for a range of incidence angles from 0-40°—and from polarization azimuths of 0° to 90°. The rotation process projects these polarizations to coordinates consistent with the HTI geometry, and is used to estimate where the cross-term energy is minimized. The numerical model has a 2 km thick isotropic layer over an HTI anisotropic layer with a 30° 'fracture' strike direction. The plot correctly indicates minima in cross-term energy at 30° and the X-X and Y-Y receiver pairs are maxima. At all other rotation angles, the cross-term energy is not zero, meaning it's not at the correct orientation. Results of a similar analysis applied to the four horizontal receiver components X (east) and Y (north) source and X (east) and Y (north) of the 9C Oklahoma Black Bear field data (c) and (d). A similar analysis was applied to a reflector at a shear-wave reflection time of 1.1 seconds. Similar to the synthetic data, there is energy on the cross-terms, which is indicative of anisotropy. Cross-term energy is a minimum at 30° and aligned X-X and Y-Y receiver pairs are energy maxima. Analysis of 9C VSP and crossed-dipole data in a nearby well (Texaco # 1 Brady Ranch) shows strong HTI anisotropy, at a 30° azimuth, in the entire shallow part of the section.

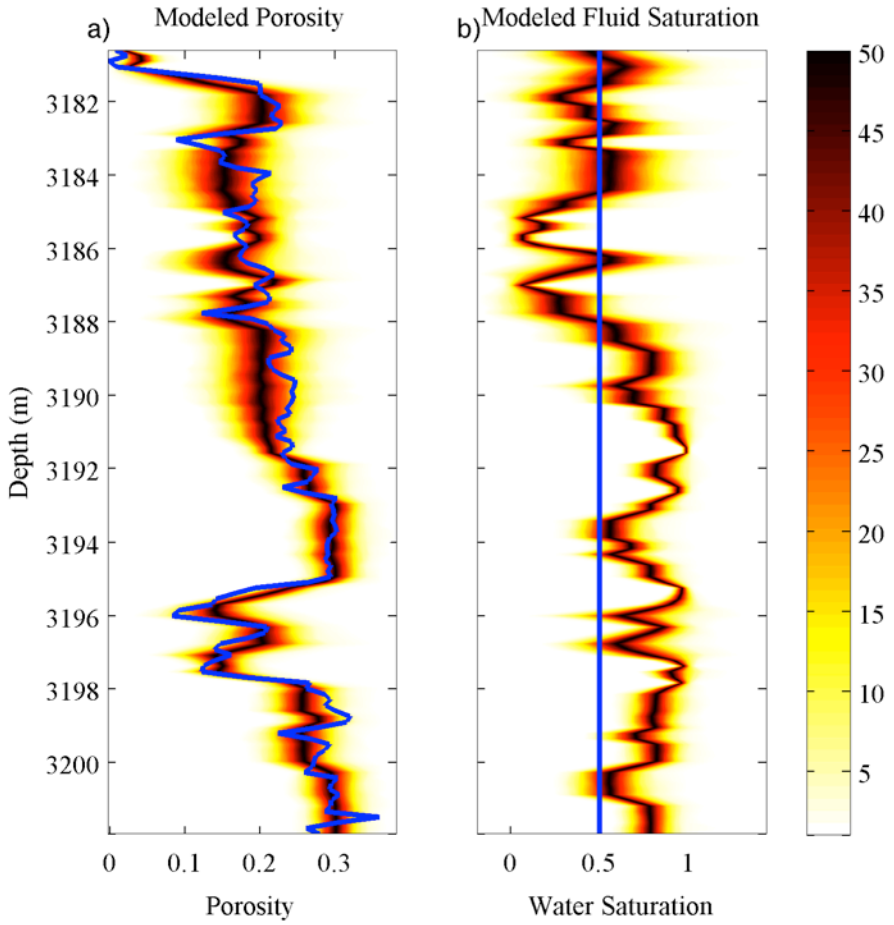
MODELING FLUID COMPOSITION IN CO_2 SATURATED SANDSTONE USING STATISTICAL ROCK PHYSICS, CRANFIELD FIELD, CRANFIELD, MS

Russell W. Carter

Department of Geological Sciences
The University of Texas at Austin

ABSTRACT

Analysis of the effects of injected CO_2 on the seismic response of reservoirs is important because it can provide improved characterization and monitoring of sites undergoing CO_2 injection. In this study we completed a joint inversion of the contact cement model to better understand the effect of CO_2 saturation on the relationship between elastic parameters and reservoir properties of the Cranfield reservoir. We used p-impedance and the Vp/Vs of well logs to invert the rock physics model for porosity and then jointly for porosity and fluid composition. We calibrated a rock physics model to well data from the Cranfield reservoir interval. For the contact cement model to bound the data and correctly model porosity at the Cranfield reservoir, a p-wave coefficient of 1.1 was needed. This term is analogous to a pressure coefficient and simulates increased velocity associated with overburden pressure. We then performed fluid substitution to model density and velocity logs for different in situ CO_2 saturations. The logs, calculated to have a uniform pore fluid composition for all depth points, were input into the inverted model to generate modeled logs of CO_2 saturation and porosity. Results indicated that the model was relatively accurate when inverted for just porosity. Joint inversion for porosity and pore fluid composition predicted porosity successfully but was not able to give as accurate a prediction of fluid composition. Porosity and fluid saturation are linked through the influence of Vp on both Ip and Vp/Vs therefore some parallel trending may arise from the joint inversion.



Results of the joint inversion for porosity and water saturation are shown in panels a) and b) respectively. The blue line shown in both panels shows the porosity and pore fluid composition for the input data in panels a) and b), respectively. The colored region in each panel represents the probability of a given porosity or saturation value being generated for a given depth point. Input CO_2 in the model has been set to a constant 50% with the remainder of the pore fluid being brine. Because of the influence of Vp on both Ip and Vp/Vs there is some parallel trending in the porosity and water saturation logs. This is most apparent at 3916 and 3187 meters in depth.

GAS HYDRATES SATURATION ESTIMATION USING GEOPHYSICAL METHODS: AN APPLICATION TO KRISHNA-GODAVARI BASIN, INDIA

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ABSTRACT

Gas hydrates are an unconventional energy resource. They may become an important possible source of energy for India and some other countries in the future energy scenario. Although a technology for economic production of gas hydrates does not currently exist, much effort is being made to explore and quantify gas hydrate saturation. The goal of this work is to present a new technique to estimate the quantity and location of gas hydrates. The region of study for the project is the Krishna-Godavari basin located on the eastern offshore of India. A 2D seismic line and well data were used for the study. The method to estimate gas hydrates saturation uses a combination of seismic inversion and seismic attributes. This includes stacked and migrated data along with well logs to perform poststack seismic inversion to obtain impedance volumes. These volumes were combined with multi-attribute analysis using a neural network method to predict anisotropic resistivity and porosity logs at the well location. Transform equations relating the seismic attributes to the well measurements predicted the petrophysical properties throughout the desired zone of interest. By using neural networks for multi-attribute analysis a statistical method for the prediction gas hydrates saturation along the complete seismic profile was obtained. The results suggest gas hydrates saturation in the range of 50–80% in the region. The estimated saturation of gas hydrates matches up very closely with the saturation readings obtained from the cores recovered during coring. Hence, the method provides a very accurate method of quantification of gas hydrates by making use of seismic and well log data.

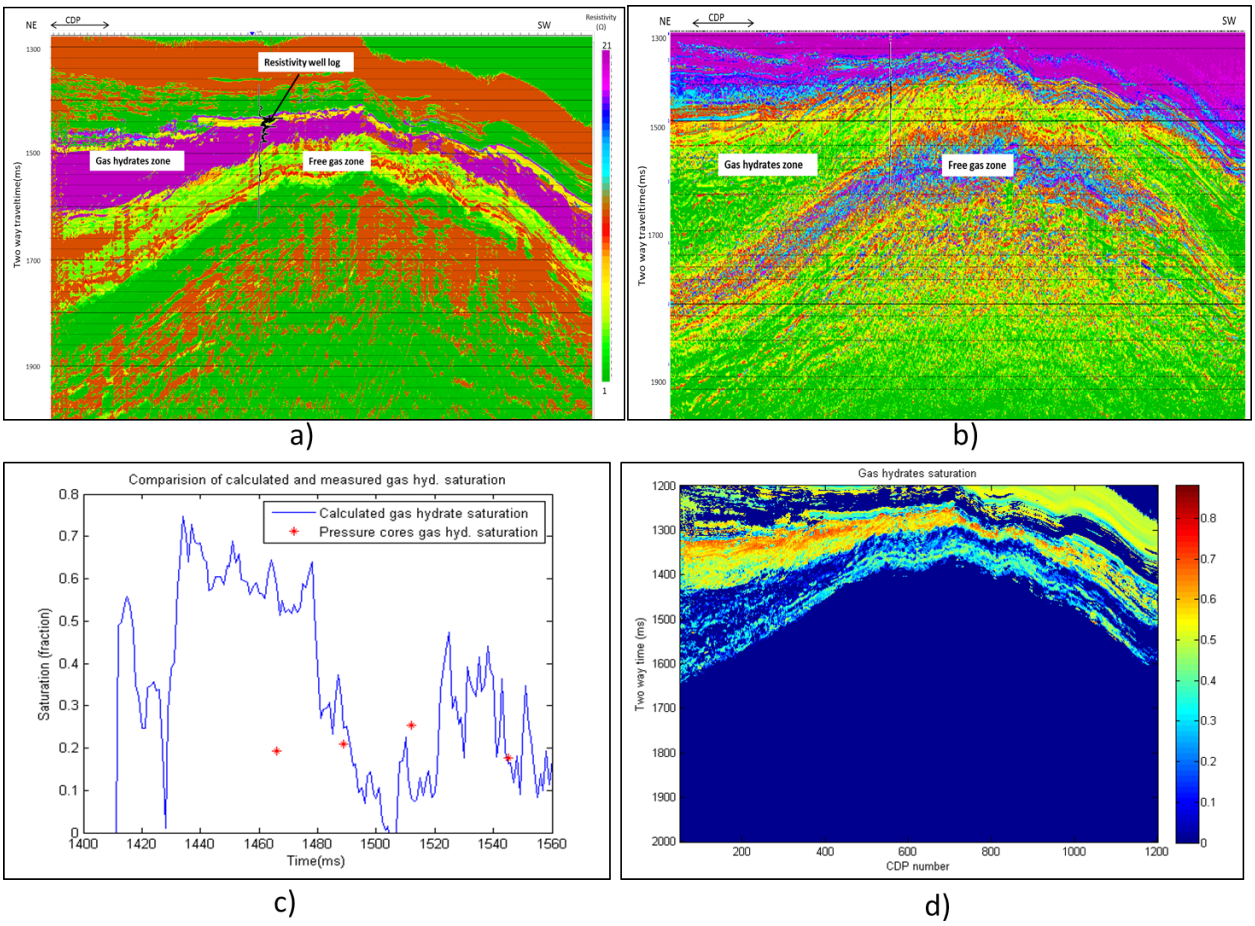

Figure a) shows the predicted resistivity and figure b) shows the predicted porosity along the 2D seismic profile. Figure c) shows the estimated gas hydrates saturation at the well using the predicted logs from figure a and figure b. The red dots are the saturation obtained from cores. The predicted saturation pseudo log matches three of the observation data points. Figure d) shows the gas hydrates saturation estimation along the seismic profile.

A WORKFLOW TO ESTIMATE RESERVOIR PROPERTIES OF UNCONVENTIONAL GAS SHALES: A CASE STUDY OF THE HAYNESVILLE SHALE

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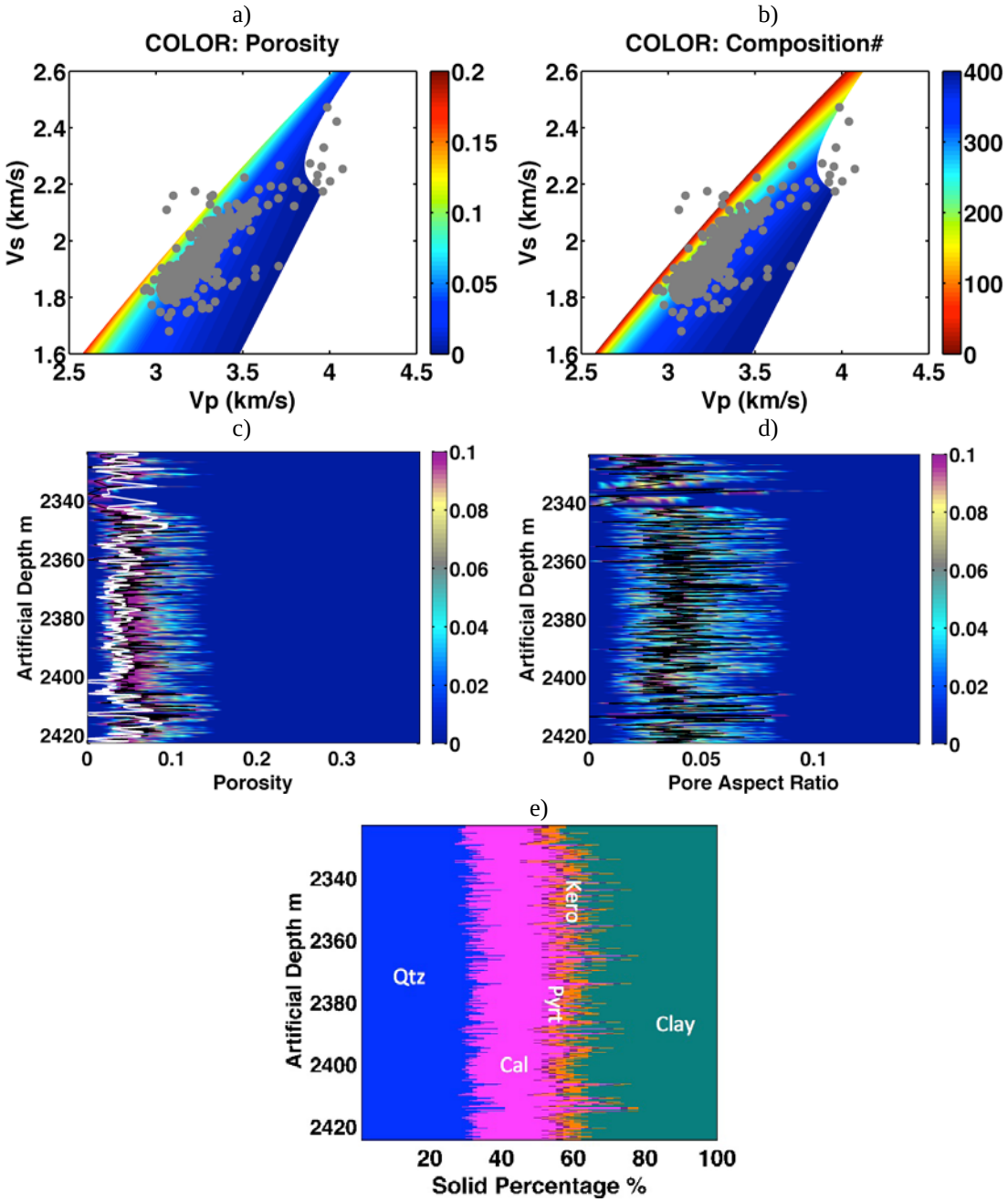
ABSTRACT

Reservoir properties, such as porosity, composition, and pore shape of gas shales are important for both exploration and production purposes of these complex reservoir rocks. This work presents a workflow to invert these properties from well log sonic data for unconventional gas shales, using the Haynesville Shale as a case study. Two rock physics models, an isotropic and an anisotropic one, were combined with a grid search method. The isotropic model initiates the numerical simulation by including grains and pores of different shapes and sizes; the anisotropic model then treats the shale as a vertical transversely isotropic medium by introducing aligned fractures. After the relationships between the reservoir properties and elastic properties (P- and S- wave velocities) were built through the rock physics models, a grid search method was used to estimate the reservoir properties and the associated uncertainties. In the grid searching, P- and S-wave velocities from the rock physics models were compared with the measured log data. The modeled seismic velocities that satisfied specific acceptance criteria provided the estimated reservoir properties. The workflow was applied to the Haynesville Shale and provided joint distributions of porosity, composition and pore aspect ratio at the well location. The porosity and composition estimations matched the observations from log and core data within a few percent. Aspect ratio estimation matched those observed in microscale images. When we apply this workflow to the seismic scale where there are continuous seismic velocities inverted from 3D seismic data, we will be able to obtain spatial distributions of these reservoir properties and, therefore, provide optimal locations for exploration and production wells.



Crossplot of Vs Versus Vp colored by porosity a) and composition b), where composition consists of quartz, calcite, pyrite, kerogen and clay. Gray dots are well log data, and the background color shows the rock physics modeling results. Almost all the data points are covered by the modeling results, and the modeling results follow the data trend very well, indicating that the model is constrained by both Vp and Vs simultaneously. Estimation of porosity c) and pore aspect ratio d) are shown, with the background color representing probability, and the black curve representing the estimation with the highest probability. For porosity estimation, the white curve shows the density porosity from log data. The estimated porosity matches with density porosity very well. Estimated percentages of quartz, calcite, pyrite, kerogen and clay e) is plotted along the artificial depth.

ROCK PHYSICS MODELING TO CONSTRAIN PETROPHYSICAL PROPERTIES IN THE PRODUCTIVE ZONE OF THE MARCELLUS SHALE, WV FROM WIRELINE LOG DATA

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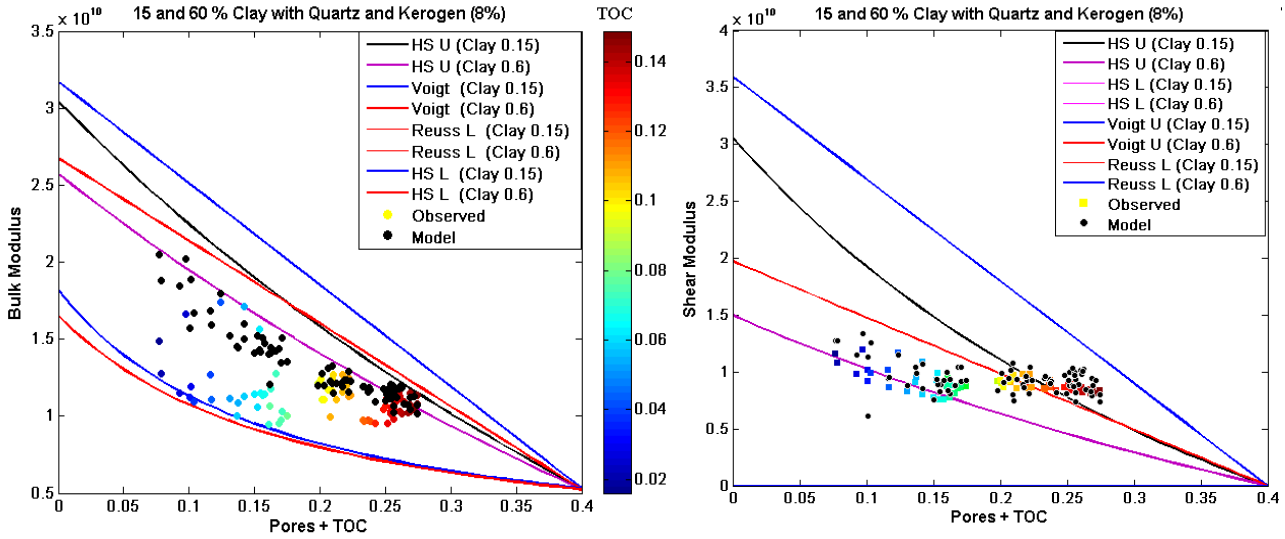
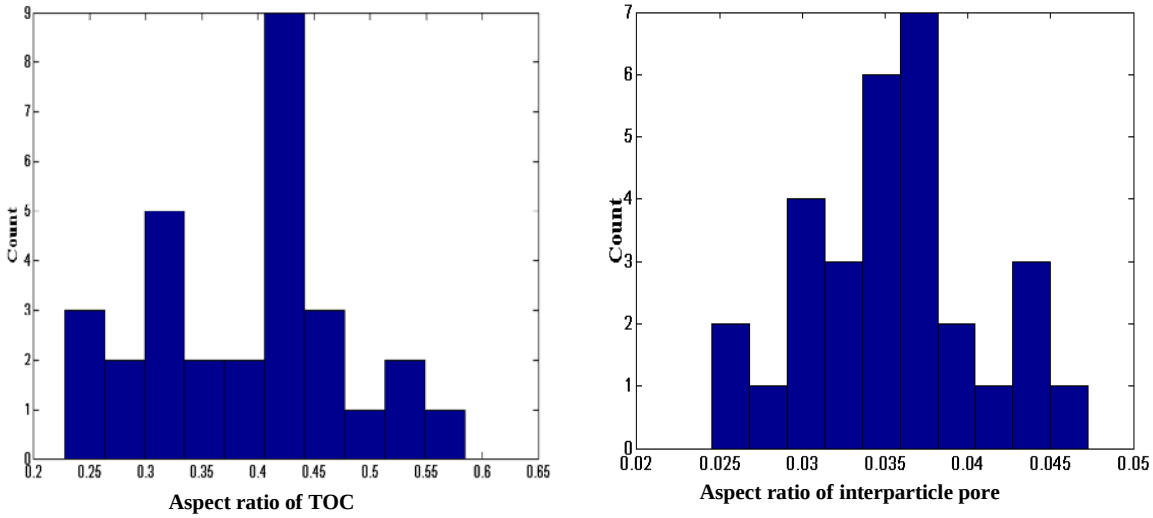
ABSTRACT

A rock physics characterization based on wireline log data is proposed for constraining the petrophysical properties of the productive interval in the Marcellus Shale. The method involves two parts, 1) petrophysical interpretation of organic shale from conventional wireline log data, and 2) rock physics modeling utilizing the interpreted data. A petrophysical interpretation of the more radioactive interval of log data suggests that higher TOC is associated with lower clay content. This interpretation also showed that upper the part of the Marcellus Shale is clay dominated whereas the lower part is quartz dominated. The interval of interest did not contain significant amount of pyrite or carbonate minerals. Following the petrophysically interpreted data, the rock physics modeling was performed using differential effective medium (DEM) scheme in an inclusion based model to estimate the effective elastic moduli of the composites. The elastic moduli of the matrix phase in the DEM were provided with the Voigt-Reuss-Hill average for a composition of quartz and clay. Imbedded inclusions were assumed. Three types of inclusion phases were considered; a dry pore (i.e. equant pores or ellipsoidal pores), a water-wet clay pore and kerogen. Dry pores were saturated with pore fluids simulating reservoir situations with the low frequency Gassmann equations. Rock physics modeling reveals that the elastic properties of the Marcellus Shale were controlled by the interplay of clay content, kerogen content and low aspect ratio pores. Low aspect ratio pores (~1/40) also comprise the dominant pore types in the Marcellus Shale and these pores are more common in the lower part of the formation. This proposed rock physics scheme constrains the dominant petrophysical properties to be applied for surface seismic data interpretation.

a) b)



c) d)



Bulk Moduli (a) and Shear Moduli (b) of the observed data and the DEM modeled data are plotted as a function of pores plus TOC. Theoretical bounding lines are also plotted for two cases; 15% clay and 8% TOC with Quartz, and 60% Clay and 8% TOC with Quartz. The Hashin-Strikman lower bound overlaps with the Reuss lower bounds. The observed data are color coded by TOC content. Both observed and model data seems to fall within the theoretical bounds. Figure c and d shows the histograms of the aspect ratios of TOC and interparticle pores considered in the DEM modeling.

P-WAVE AND S-WAVE ANGLE DEPENDENT VELOCITY PREDICTION THROUGH PRESSURE-DEPENDENT COMPLIANCE COMPONENTS

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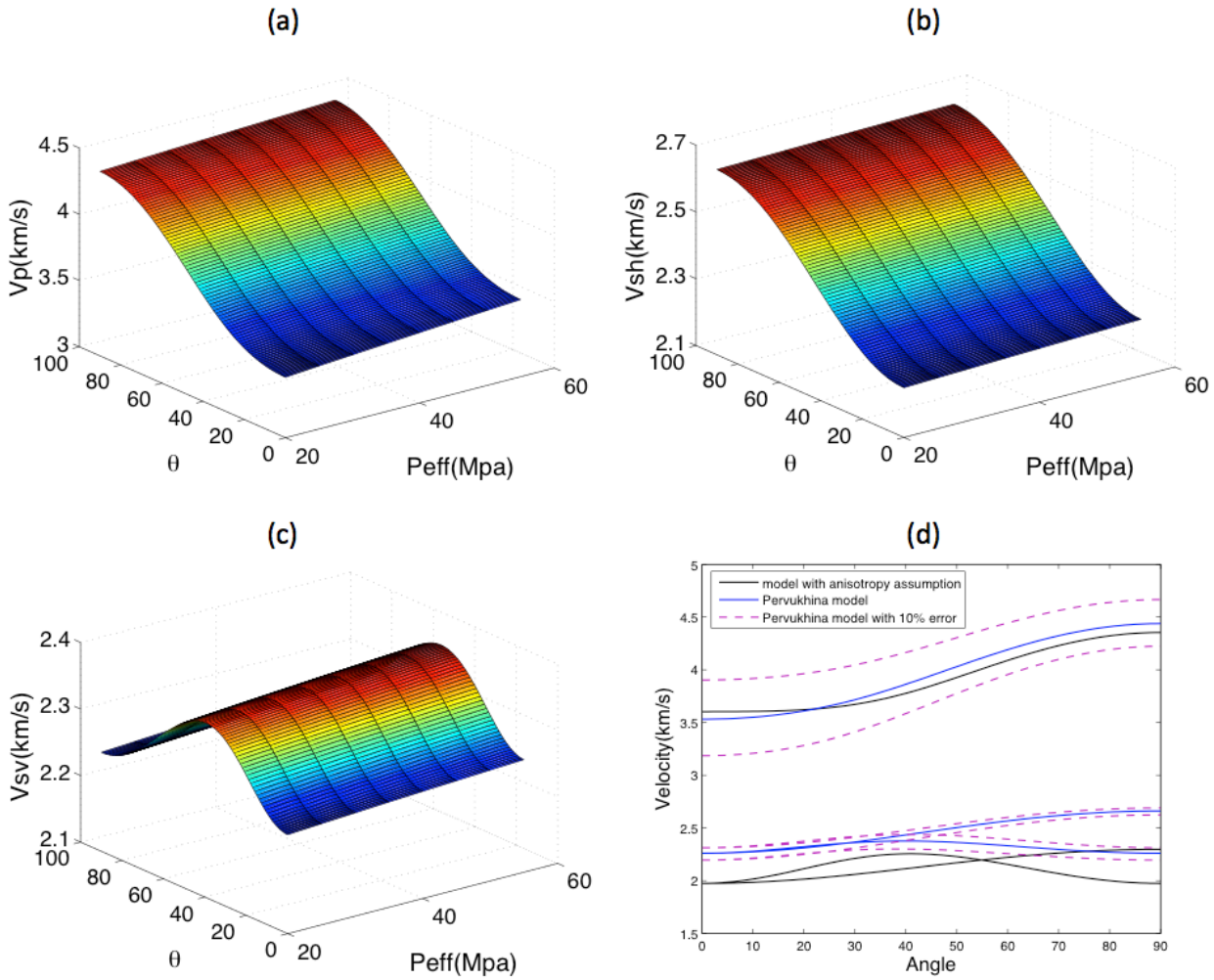
ABSTRACT

Worldwide interest in shale as a hydrocarbon resource requires new approaches to reservoir characterization. Due to its intrinsic anisotropic properties (commonly VTI), the existing isotropic rock physics models are no longer suitable in shale studies. Therefore, it is important to utilize anisotropic rock physics models for shale in further research. These anisotropic models should account for the phase velocity with non-zero propagation angles with respect to the reference frame. My work was aimed at developing a feasible method to predict angle-dependent velocities (P, SH and SV) in a VTI system. In such an anisotropic system, wave velocities are determined by the elastic tensor with five independent components. The well data I used was from the Haynesville Shale, core samples from this well, and an analogous hard shale sample. The model used to describe the VTI system treats the compliance tensor components as an exponential function of effective pressure. I built an integrated workflow to model the compliance tensor from stress-dependent vertical P-wave velocity lab measurements and then predicted the velocities. Then I used the log data and analogous shale data to estimate the uncertainty. The difference between well log and modeled P-wave results at a test location was 3%. The modeled P-wave results fell between 10% uncertainty estimates over the range of propagation angles. For the S-wave, the difference was much larger due to the lack of measurements, but they showed the same angle-dependent variation trends. Therefore, the analogous data was required to provide reliable S-wave velocity. Applying these results to field seismic data, we could reliably predict the angle-dependent P-wave velocity at the seismic scale.



Predicted velocity against propagation angle and effective pressure, colored in velocity. a) P-wave; b) SH-wave; c) SV-wave. As the increasing of propagation angle, Vp, Vsh increase, and Vsv shows more complex behavior. d) shows the uncertainty of the predicted velocities (blue lines). Black lines are the log-based angle-dependent velocity using hard shale Thomsen parameters and green dash lines are predicted velocity with 10% error. P-wave uncertainty is less than 10%, while S-wave uncertainties are larger.

MODELING OF 4D SEISMIC RESPONSE AT THE NORNE FIELD

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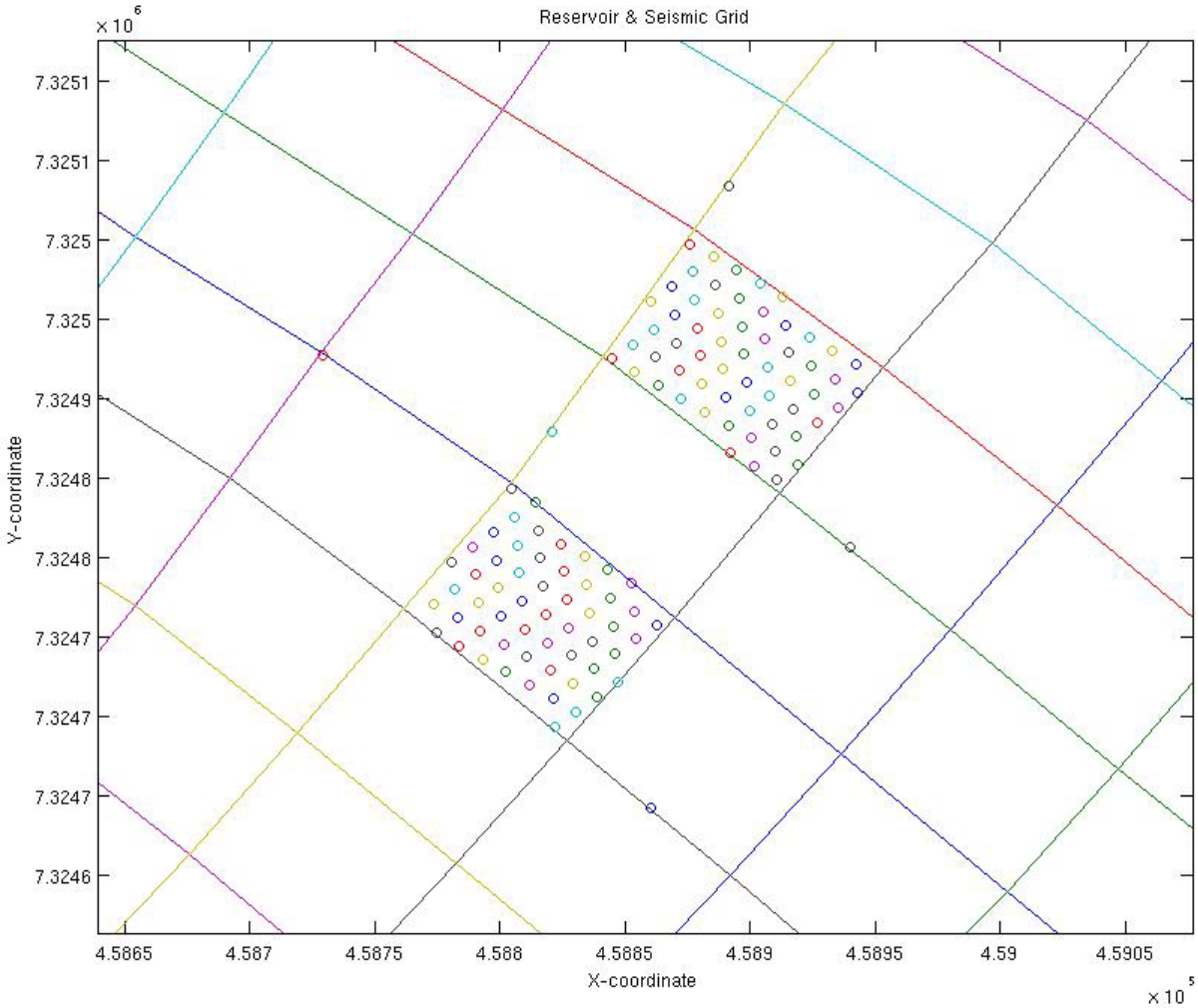
ABSTRACT

A time lapse seismic forward modeling study of an offshore producing oil and gas field in the Norwegian Sea is being developed. Forward modeling of 4D seismic data is an important tool in both feasibility studies and interpretation of time-lapse data. By combining rock physics modeling and fluid-flow simulation, the seismic parameters, Vp, Vs and densities can be calculated at different times for different fluid states. A 3D modeling code will then be used to predict the seismic response. The first step of the modeling is to create an isotropic seismic model on a regular grid, populated with values of Vp, Vs, and density at each node. The seismic grid then needs to be linked to the reservoir simulation grid so that velocities and densities can be calculated as a function of reservoir parameters. The reservoir simulation grid is much coarser than the seismic grid, and it consists of cells instead of nodes. Further, the reservoir simulation grid is not a regular grid but based upon corner point geometry. To check if a seismic node is horizontally within a reservoir simulation grid cell, a vector is calculated from one of the corners of the cell to the seismic point. If the seismic node is within the cell, then the angle between the corner lines should be larger than between each of the corner lines and the vector. If this is true for all corners in the cell, the seismic node is horizontally within the cell.



The figure shows a few reservoir simulation gird cells divided by lines, seen from above. Two of the cells, have been filled with corresponding points in the seismic grid, using the algorithm described above. A few seismic points fall outside of the two reservoir grid cells, caused by an inaccurate angle calculation in the algorithm. These points represent only a small fraction of the total number of nodes, so this is not assumed to be an important issue.

ERROR ESTIMATES OF ELASTIC TENSOR COMPONENTS IN STRESS-DEPENDENT VTI MEDIA

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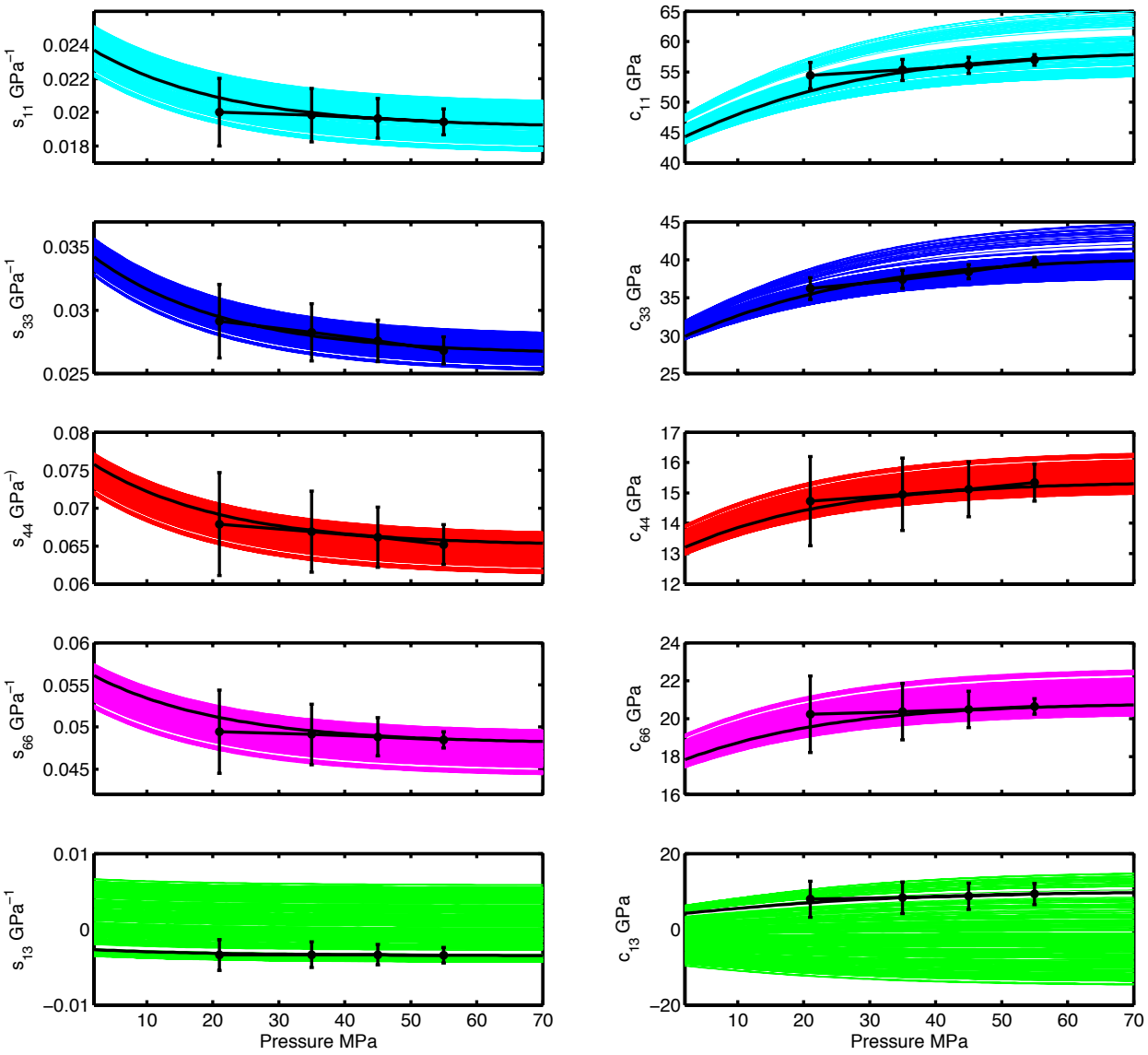
ABSTRACT

This work examines the range of physically acceptable VTI stress tensor components for a laboratory shale dataset. The importance of this work is to demonstrate the potential model-based variability and associated error of elastic compliance and stiffness components that are physically acceptable. Laboratory data and a statistical rock physics approach provide the basis for this study. Velocity measurements made as a function of pressure on a low porosity, hard shale provide the basis for completing this work. In terms of a rock physics model, a pressure-dependent model was used to represent simultaneously five compliances at any given pressure from 20–70 MPa. This model requires specifying compliances at high pressure (5 independent parameters), plus four others. These four are a characteristic pressure, the ratio of tangential to normal compliance, the anisotropic crack orientation parameter, and the product of the tangential compliance and the specific surface area of cracks per unit volume. Prior distributions of the five compliance components and the rock physics model provided the parameter space. Acceptable solutions were constrained to several criteria including energy requirements, relative values of stiffness coefficients, and relative values of calculated anisotropic parameters. Multiple solutions were validated, and criterion relating compressional to shear waves was violated most frequently was an inequality relating shear and compressional stiffnesses. Differences between the models and data indicate error in the data or that the samples deviate away from a true VTI medium. These simulations provide a way to analyze the elastic tensor components, and they provide uncertainty estimates useful in seismic inversion and imaging techniques.



Solutions for the compliance components in the left column and stiffness components in the right column for a subset of the simulations. A total of 805 simulations over all pressures were considered, and 287 passed on the checks for energy requirements and other cut off criteria. Considering the overall fit of all models to the original model (in black), the 11 and 33 terms are likely the best fits, followed by the 44 and 66 terms. However, the 13 terms are skewed notably above (compliance) and below (stiffness) the original model and data. This suggests the sensitivity of this parameter. The inconsistent match of the range of models from one component to the next also suggests that more error is present in the 44, 66, and 13 data than in the 11 and 33 data components. An alternate scenario is that these samples are not absolutely VTI.

FREQUENCY-DOMAIN FULL WAVEFORM INVERSION WITH PLANE-WAVE DATA

Yi Tao[1] , Mrinal K. Sen[2]

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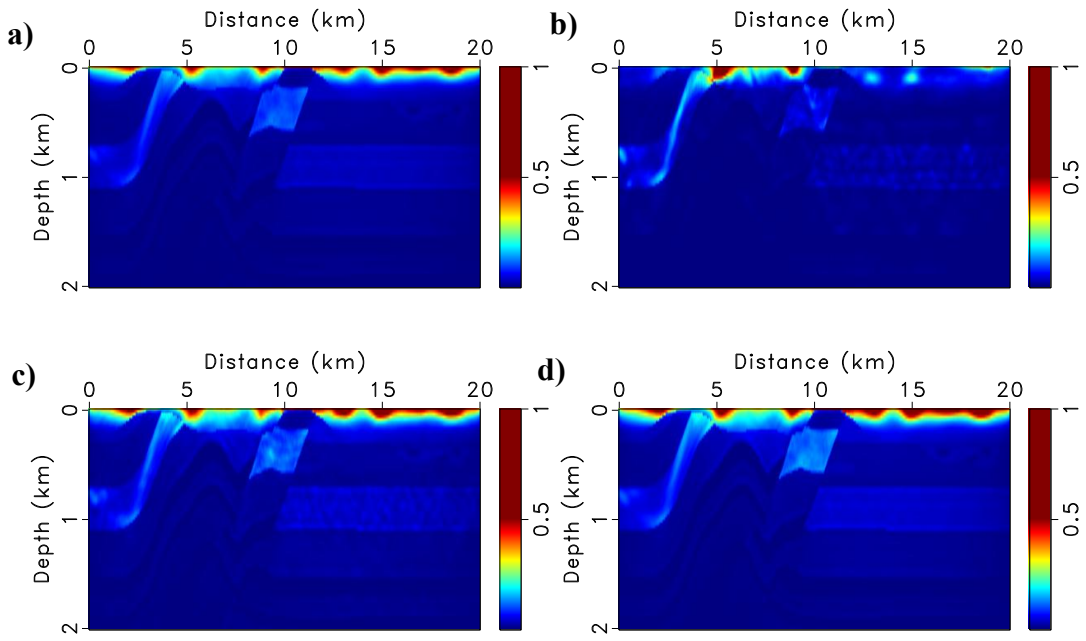
[2]*The University of Texas at Austin and National Geophysical Research Institute, India*

ABSTRACT

We propose an efficient frequency-domain full waveform inversion (FWI) method using plane-wave encoded shot records. The forward modeling involves application of position dependent linear time shifts at all source locations. This is followed by propagation of wavefields into the medium from all shot points simultaneously. The gradient of the cost function needed in the FWI, is calculated first by transforming the densely sampled seismic data into frequency-ray parameter domain and then back-propagating the residual wavefield using an adjoint-state approach. We use a Gauss-Newton framework for model updating. The approximate Hessian matrix is formed with a plane-wave encoding strategy, which requires a summation over source and receiver ray parameters of the Green's functions. Plane-wave encoding considerably reduces the computational burden and cross-talk artifacts are effectively suppressed by stacking over different ray parameters. It also has the advantage of directional illumination of the selected targets. Numerical examples show the accuracy and efficiency of our method.



Comparison of the diagonal Hessian for the true model with different parameters. (a) true Hessian with 401 sources and 401 receivers; (b) plane-wave Hessian with 9 source and receiver ray parameters; (c) plane-wave Hessian with 41 source and receiver ray parameters; (d) plane-wave Hessian with 81 source and receiver ray parameters.

SUPPRESSING NON-GAUSSIAN NOISES WITH SCALED RECEIVER WAVEFIELD FOR REVERSE TIME MIGRATION

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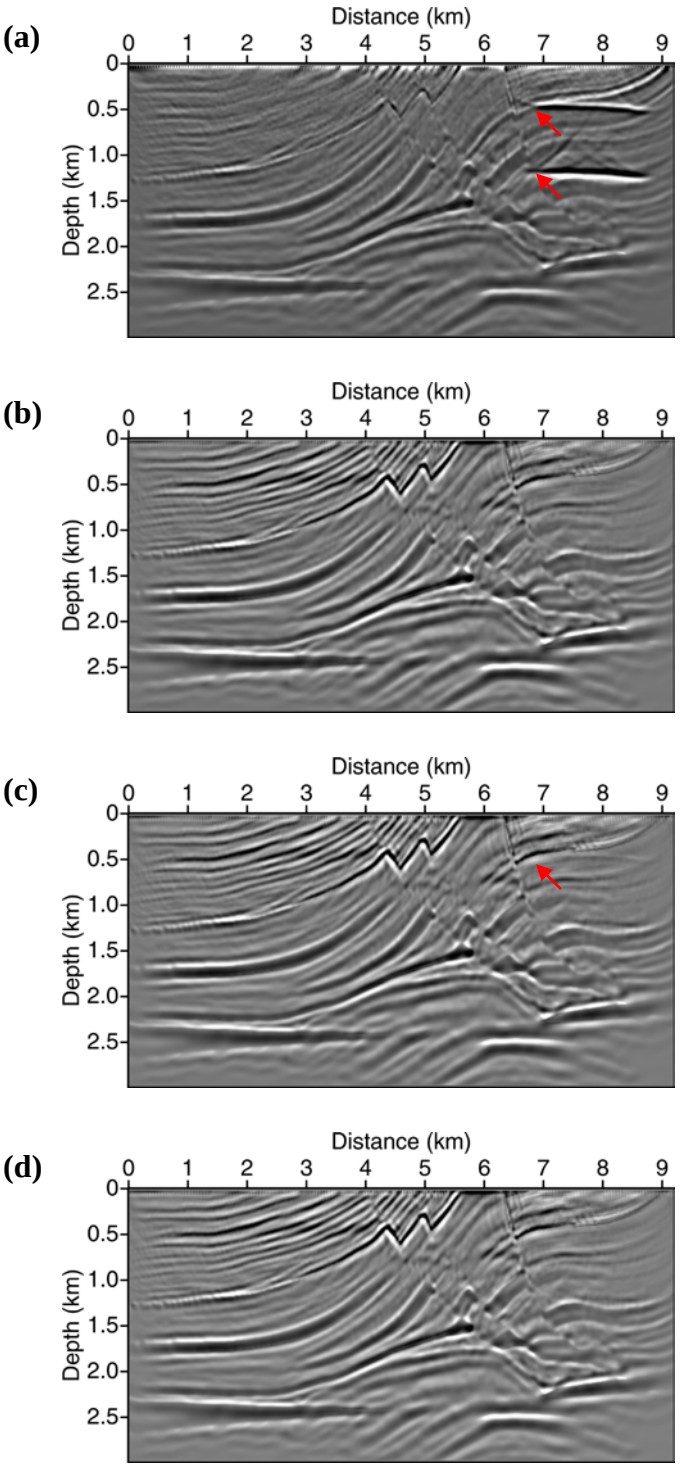
[2]*The University of Texas at Austin and National Geophysical Research Institute, India*

ABSTRACT

Numerical implementation of the gradient of the cost function in a gradient-based full waveform inversion (FWI) is essentially a migration operator used in wave equation migration. In FWI, minimizing different data residual norms results in different weighting strategies of data residuals at receiver locations prior to back propagation into the medium. In this dissertation, we propose different scaling methods to the receiver wavefield and compare their performances. Using time-domain reverse time migration (RTM), I show that compared to conventional algorithms, this type of scaling is able to significantly suppress non-Gaussian noise, i.e., outliers. Numerical tests also show that scaling by its absolute norm produces better results than other approaches.



Reverse-time migrated image for the Marmousi model. (a) with conventional method; (b) with scaling by receiver data's absolute norm (L-1 norm approach); (c) with a hybrid norm scaling approach; (d) with scaling on the logarithmic wavefield.

COMPARISON OF OPTICAL AND ELASTIC BREWSTER'S ANGLES TO PROVIDE INVUITIVE INSIGHT INTO PROPAGATION OF P- AND S-WAVES

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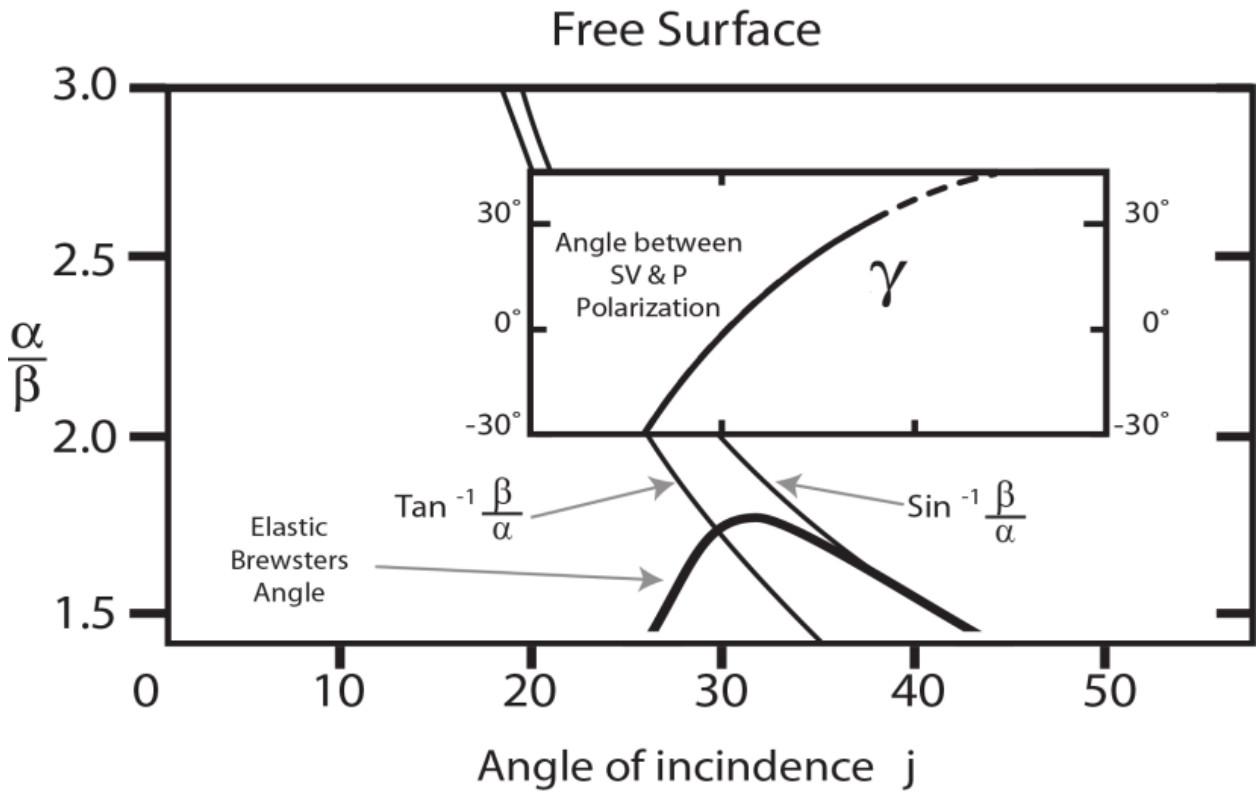
ABSTRACT

The Brewster's (polarization) angle of reflection in optics is well understood and leads to distortion, including polarization filtering, of reflected waves. Further, the values of the Brewster's angle (a zero crossing in amplitude) are closely related to the contrast in physical properties across the reflecting interface. I investigate elastic analogues to the optical Brewster's angle for the case of incident seismic shear waves at a reflecting interface. Both optical (light) and elastic shear waves are characterized as transverse waves, and both are subject to polarization distortion upon reflection. For this exploratory study, I limit the seismic case to situations of only two reflected or transmitted waves where one of the waves vanishes 1.) SH-SH reflection-refraction across a solid-solid interface where the reflected SH wave vanishes and 2.) SV-P reflection (mode conversion) at a free interface where the reflected SV wave vanishes. In the optical case, the rays defining the refracted and reflected waves at the Brewster's angle are at 90° to each other. In the shear-wave examples, the reflected and refracted SH waves are normal to each other only if there is no density contrast. For the free surface, the rays for the incident SV and reflected P waves are at right angles only for a Poisson's solid, $\lambda = \mu$. Understanding these geometric relations should improve our intuitive insight into reflection, refraction and mode-conversion processes for P, SV and SH waves and improve interpretation of contrasts in elastic properties, including anisotropic conditions. Further investigations into characterizing contrasts in elastic properties through reflection/refraction/mode-conversions processes are continuing.



Angle of incidence j where the amplitude of the reflected SV polarized shear wave from a free-surface interface vanishes (elastic Brewster's angle), as a function of α/β. The angle γ is the angle between the polarization direction of the input SV wave and the polarization of the reflected P-wave. Values of γ for the range of j where there is a zero crossing in Rsv-sv (only P-wave reflected) are included in the insert. In the optical case, γ is always zero.

CHARACTERIZATION OF SATURATED POROUS ROCKS WITH OBLIQUELY DIPPING FRACTURES

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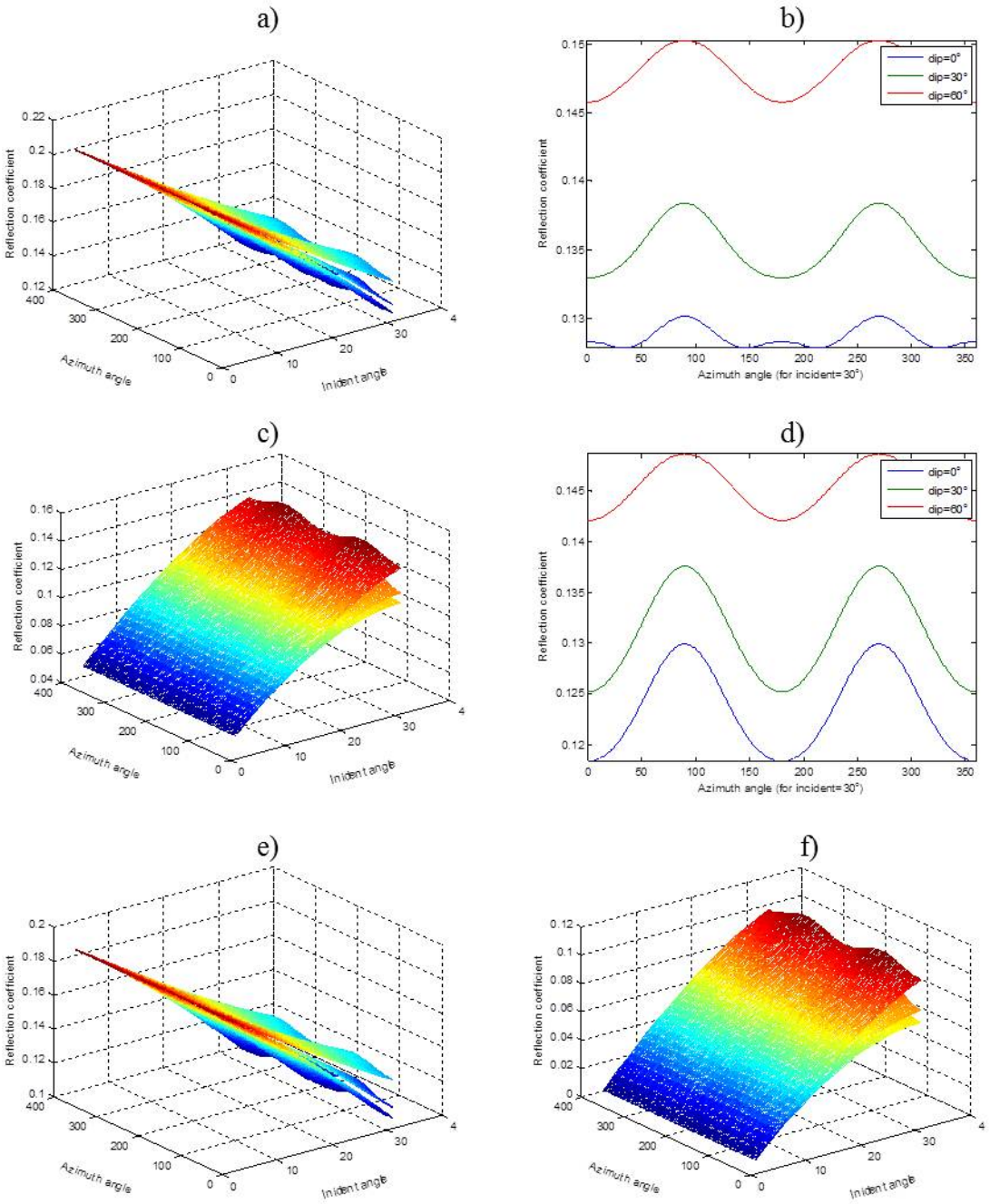
ABSTRACT

Elastic properties, fracture parameters and amplitude variation with offset and azimuth (AVOA) of fluid saturated porous media with obliquely dipping fractures are studied. Effective stiffness and anisotropy parameters for porous media with vertical fractures are studied using Gassmann's equation for linear-slip theory and fractured models developed by Hudson and Thomsen. Linear-slip theory and Hudson's model for penny-shaped cracks can be used to relate the anisotropic parameters to the fracture properties. Considering porous rocks with saturated penny-shaped cracks and hydraulically connected cracks and pores, normal and tangential weakness of the fractures are related to fluid factor, and can be obtained by making the anisotropic parameters for linear-slip model be identical to anisotropic parameters given by Thomsen. The effect of fluid infill on elastic properties is investigated. Using the Bond transformation, the stiffness matrix of the dipping fractured medium can be obtained. Then, characterization of fluid saturated porous rocks with obliquely dipping fractures is investigated, and variation of reflection coefficients as a function of azimuth and incidence angle is analyzed. For the saturated porous rocks with obliquely dipping fractures, the effect of porosity, fluid infill and dipping angle on horizontal and vertical velocities, anisotropic parameters and reflection coefficients are examined. In the end, we estimated the dip of dipping fractures by AVOA analysis, and obtained fracture parameters from synthetic reflection data. Results show that this estimation method yields dip angle with reasonable accuracy, and inversion results are consistent with the model.



The effect of porosity and fluid infill on amplitude variation with azimuth and incidence angle is shown. Small porosity of 10% and large porosity of 25% are considered. a) and b) are water saturated fractured porous model with porosity of 10%; reflection amplitude decreases with the increase of incident angle. c) and d) are water saturated model with porosity of 25%; reflection amplitude increase with the increase of incident angle. For small incident angle, reflection coefficient variation with azimuth is almost not visible. This is because the fracture density is small. The variation with azimuth is more visible for larger porosity. For gas saturated fractured porous rock e) and f), we obtained similar results.

APPLICATION OF PRINCIPAL COMPONENT ANALYSIS TO SIMULTANEOUS SEISMIC INVERSION

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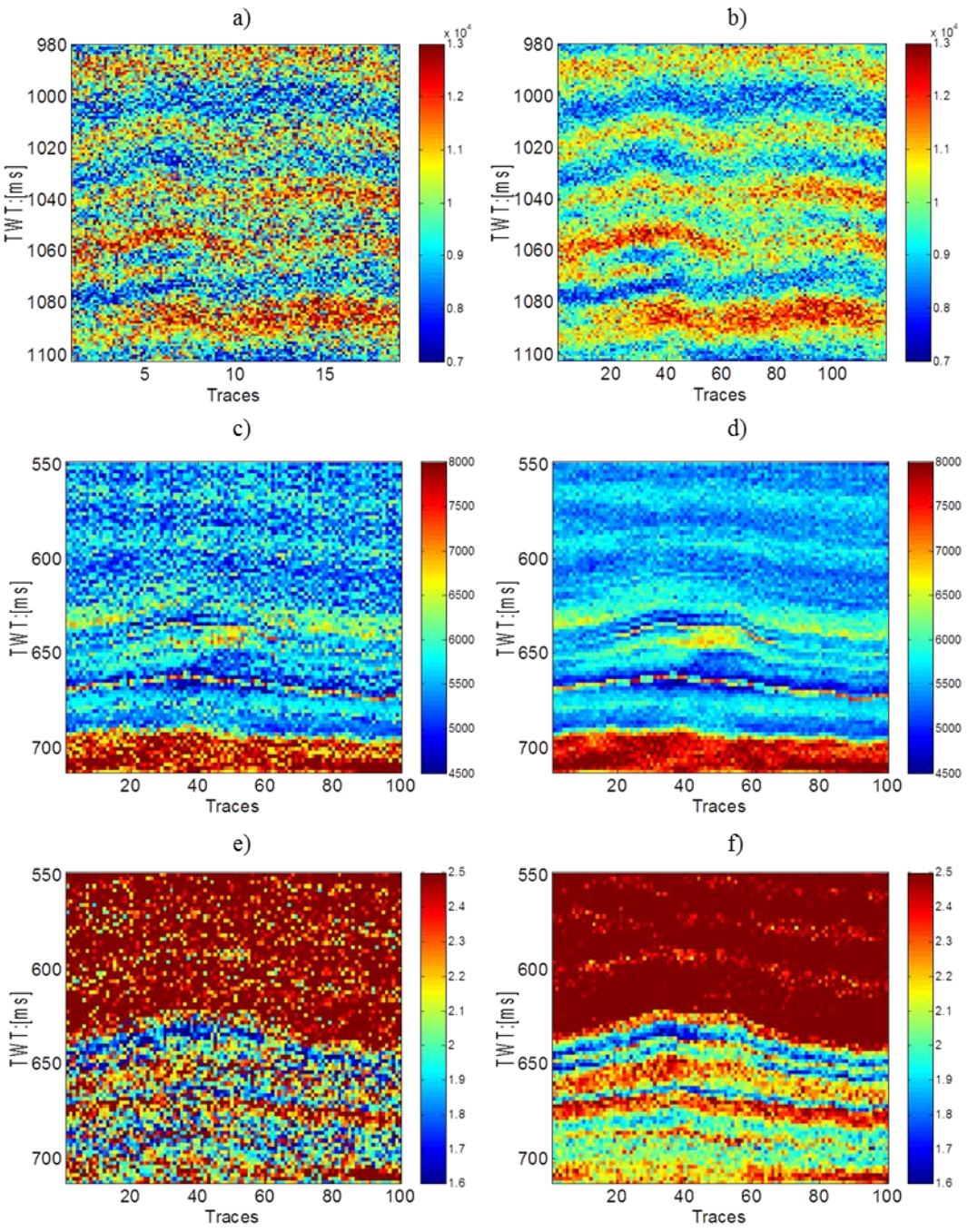
ABSTRACT

The Principal component analysis (PCA) uses an orthogonal linear transformation to project the model space with large dimensionality to a small subsurface dimension by taking advantage of strong correlation between models. In this paper, we apply PCA as an efficient parameterization tool for simultaneous seismic inversion. We start with a large number of training images sampled from the prior probability distribution. Principal components are then calculated from the covariance matrix derived from these training images. Since the number of principal components (PCs) is much smaller than the original number of model parameters, new images in posterior probability distribution can be efficiently reconstructed by only updating the weights of the PC. In this paper, we applied PCA based VFSA to both post-stack and pre-stack seismic data to invert for 2D impedance profiles. The results from simultaneous inversion demonstrate better lateral continuity than a trace-by-trace inversion using the same optimization tool. The same workflow can also be applied to 3D seismic volumes.



P-impedance profile derived from post-stack data using trace by trace inversion of VFSA a), compared with using simultaneous inversion of PCA based VFSA b); P impedance profile derived from another pre-stack data using trace by trace inversion of VFSA c), compared with using simultaneous inversion of PCA based VFSA d); Profile of P and S impedance ratio derived from pre-stack data using trace by trace inversion of VFSA e), compared with using simultaneous inversion of PCA based VFSA f).

TIME-LAPSE SEISMIC DATA REGISTRATION AND INVERSION FOR CO_2 SEQUSTRATION STUDY AT CRANFIELD

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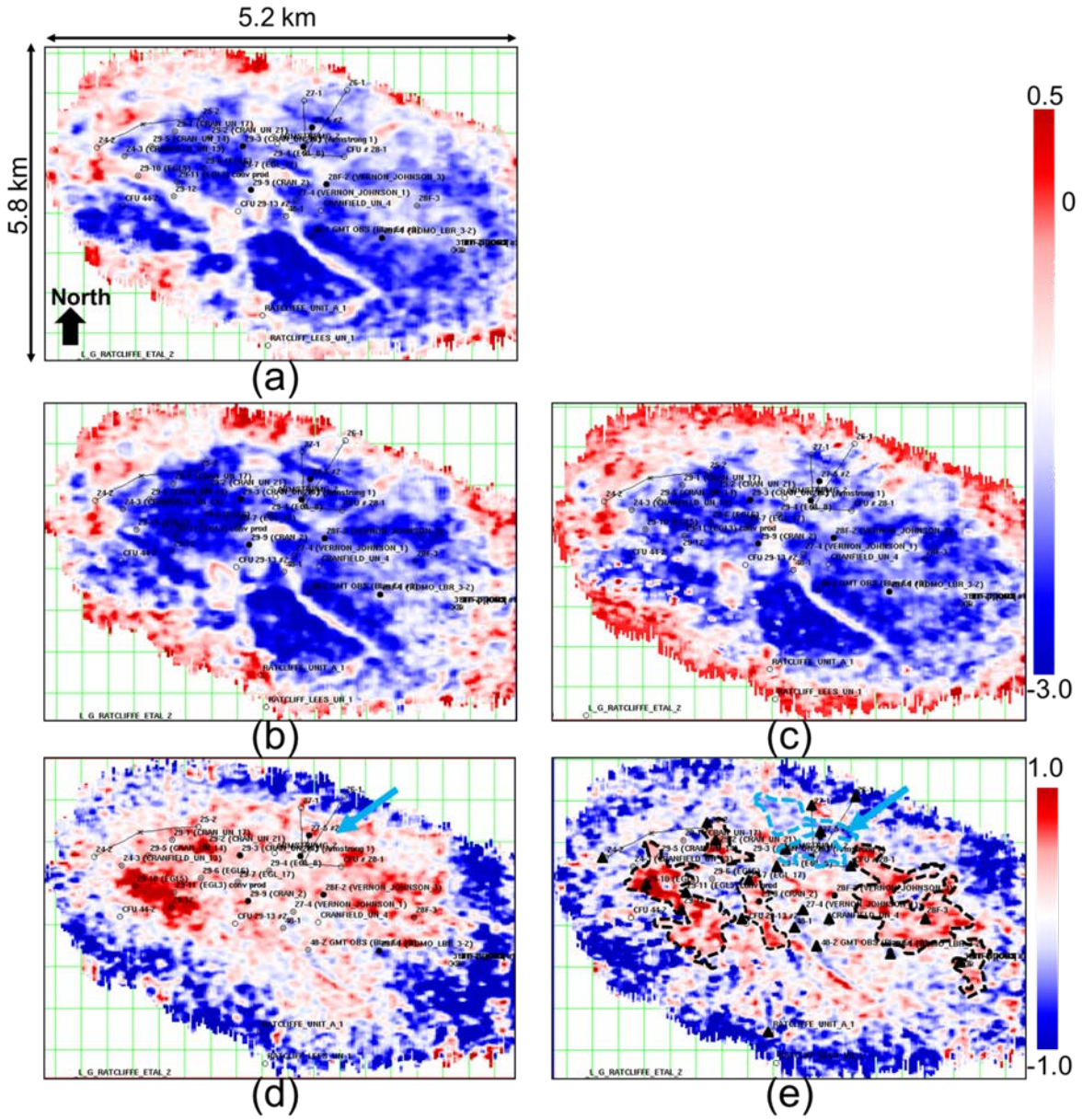
ABSTRACT

Time-lapse seismic survey for CO_2 sequestration study at Cranfield can be problematic because of misalignments between the time-lapse datasets. Such misalignments can be caused by any step of seismic data processing workflow, which may result in misunderstanding of time-lapse seismic amplitude differences. There are many matching processing methods under development, but these methods are still immature and very time consuming. We propose an efficient local-correlation based warping method to register the time-lapse post-stack datasets, which can align the time-lapse datasets without changing the original amplitudes. The application of the registration of Cranfield time-lapse datasets demonstrates its effectiveness in separating the time-shift character from the seismic amplitude signature. After registration, the time-lapse differences show improved consistence in vertical cross-sections and more localized distribution of the difference amplitudes in horizon slices, which allows us to apply a basis pursuit inversion for acoustic impedances. The inversion results show that decreases of acoustic impedances mostly occur at the top of the injection interval, which can be used as alternative rock properties to detect the subsurface CO_2 plume.



Time-lapse seismic amplitudes and their difference slices are extracted at the top of the injection interval. (a) shows the pre-injection slice; (b) and (c) show the post-injection slices before and after registration; (d) and (e) show the time-lapse difference slices before and after registration.

DOUBLE PLANE WAVE DEPTH MIGRATION

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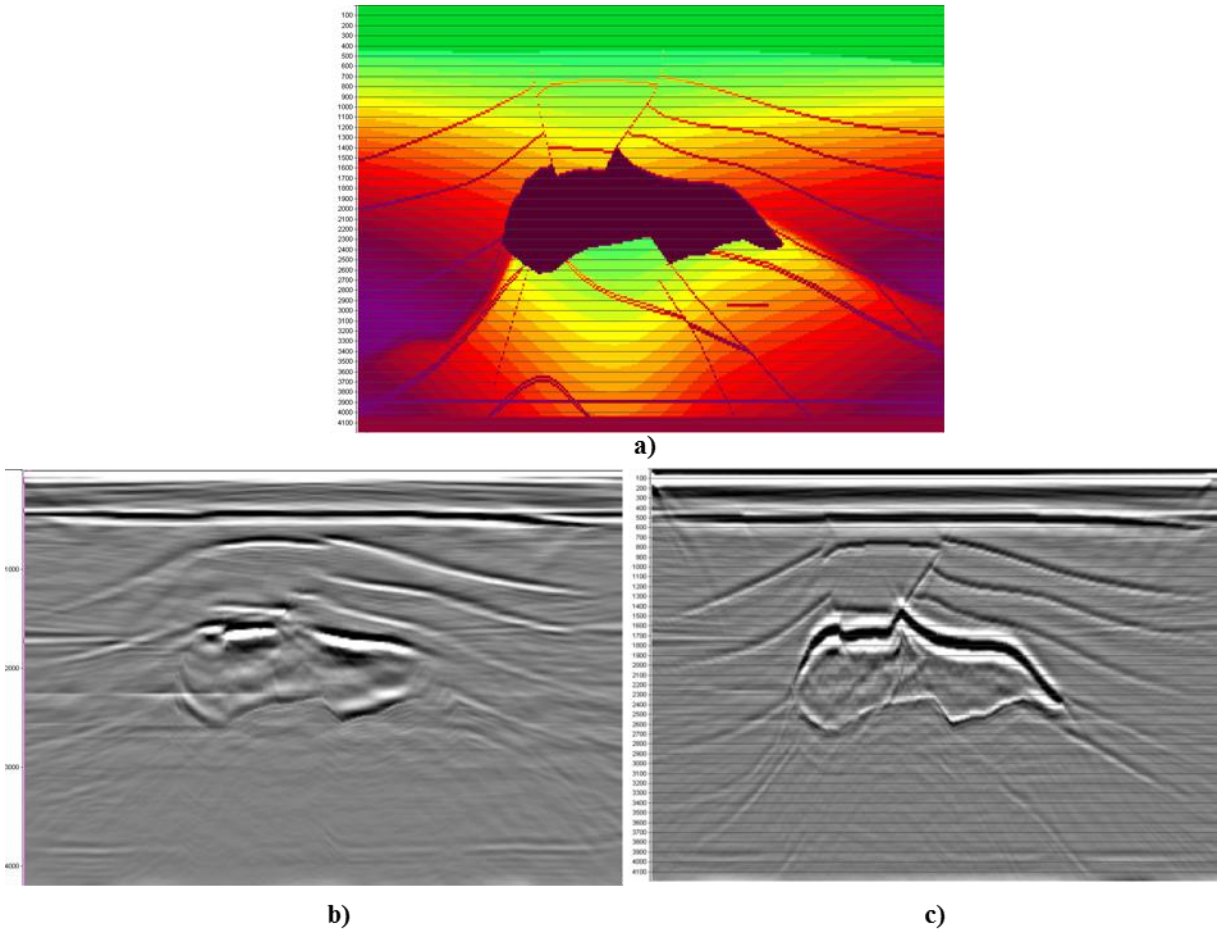
The University of Texas at Austin

ABSTRACT

The double plane wave depth migration was introduced by Stoffa and Sen et al. (2006). The method is quite suitable for the densely sampled seismic acquisition system whose size of the data volume is tremendous. Typically used Kirchhoff migration uses each shot and receiver position to do the wavefield extrapolation, which will greatly increase the calculation time when the dataset is large. Nevertheless, by transforming the dataset form the t-x (traveltime-offset) domain to the tau-p (vertical delay time-ray parameter) domain, we can shrink the number of traces needed to be migrated with enough horizontal and vertical resolution. As a type of Kirchhoff migration, the double plane wave depth migration needs to calculate the traveltime tables of plane wave components, however, the amount of traveltime tables of plane wave components needed to calculate is far less than those of the typical Kirchhoff migration. And we can even use the same traveltime table for both the source and receiver plane wave components which have same incident angle at the surface. Besides that, we can also select a range of plane wave components that we want to use in the migration according to the pre-geological knowledge of the subsurface condition, which would further reduce the calculation time. The method will be illustrated by introducing the double slant stacking which transforms the data from the t-x domain to the source and receiver plane wave domain, then the migration method will be derived by using Kirchhoff-integral. I will demonstrate that the double plane wave depth migration enjoys the high efficiency as well as accuracy, the method has great potential to be used into the migration velocity analysis process and it is easy to incorporate the anisotropic effect.



a)

b) c)

SEG/EAGE salt velocity model is shown in a) which has 675*210 grid points. Both horizontal and vertical interval is 0.02km. Shot gathers, which has 240 maximum receivers simulating the marine acquisition process from left to right, were obtained and used for double slant stacking and then double plane wave migration. Plot b) shows the image of migrating 121 receiver plane waves and 21 source plane waves which are mainly horizontal plane wave components. Most horizontal structure can be imaged. Plot c) shows how the image looks like by migrating 121 receiver plane waves and 121 source plane waves.

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