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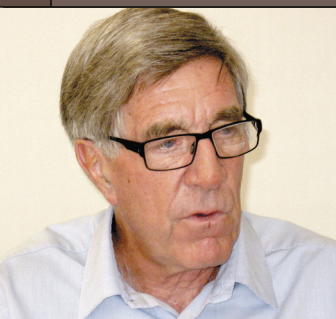
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Executive Committee 2010-2011



President
John Townsley
ARC Resources Ltd.
Suite 2100,
440 - 2nd Avenue SW
Calgary, AB T2P 5E9
Phone: 403-509-6450

jtownsley@arcresources.com



Vice President
Larry Herd
Boyd Petrosearch
1200, 800 - 6th Avenue SW
Calgary, AB T2P 3G3
Phone: 403-543-5362

larryh@boydpetro.com

Educational Services



Director
John Fernando
S.A.I.T.
1301 - 16th Avenue NW
Calgary, AB T2M 0L4
Phone: 403-210-4481

john.fernando@sait.ca



Assistant Director
Mike Perz
ARCIS Corporation
2600, 111 - 5th Avenue SW
Calgary, AB T2P 3Y6
Phone: 403-781-1709

mperz@arcis.com

Member Services



Director
David Nordin
Nordin Resource
Consultants
4019 Grovehill Road SW
Calgary, AB T3E 4E5
Phone: 403-701-3559

denordin@telusplanet.net



Assistant Director
Barrie Jose
Sproule Associates Limited
900, 140 - 4th Avenue SW
Calgary, AB T2P 3N3
Phone: 403-294-5574

barrie.jose@sproule.com

Finance



Director
Kelly Jamison
Divestco
500, 440 - 2nd Avenue SW
Calgary, AB T2P 5E9
Phone: 403-781-2317

kelly.jamison@divestco.com



Assistant Director
Pratt Barndollar
Talisman Energy Inc.
2000, 888 - 3rd Street SW
Calgary, AB T2P 5C5
Phone: 403-920-8298

pbarndollar@talisman-energy.com

Communications



Director
Kristy Manchul
CGGVeritas
2200, 715 - 5th Avenue SW
Calgary, AB T2P 5A2
Phone: 403-205-6243

kristy.manchul@cggveritas.com



Assistant Director
Cheran Mangat
Fugro-Jason Canada
610, 600 - 6th Avenue SW
Calgary, AB T2P 0S5
Phone: 403-263-3340

cmangat@fugro-jason.com



Past President
Jon Downton
CGGVeritas Processing
2200, 715 - 5th Avenue SW
Calgary, AB T2P 5A2
Phone: 403-205-6175

Jon.downton@cggveritas.com



Managing Director
Jim Racette
Canadian Society of
Exploration Geophysicists
600, 640 - 8th Avenue SW
Calgary, AB T2P 1G7
Phone: 403-262-0015

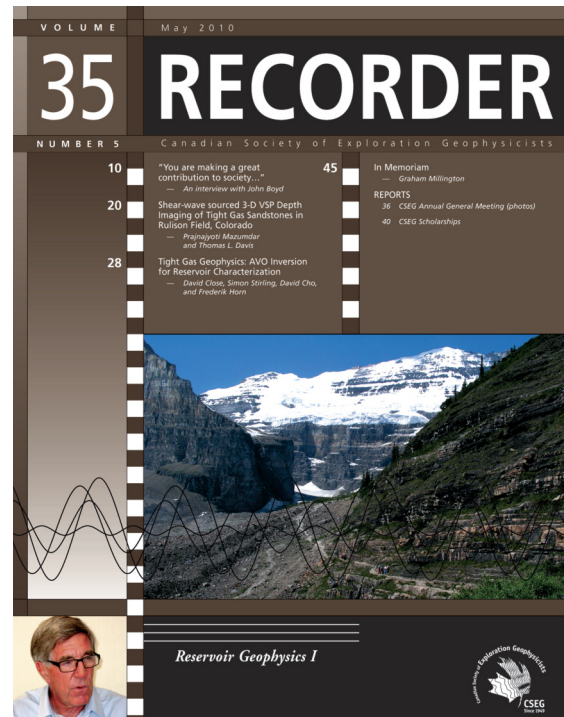
jimra@shaw.ca

"Organized to promote the science of geophysics and to promote fellowship and co-operation among our members"

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CSEG OFFICE ADDRESS

600, 640 - 8th Avenue SW, Calgary, Alberta T2P 1G7
Office Hours: 8:30-11:30, 12:00-4:00 Monday-Friday
Managing Director: Jim Racette email: jimra@shaw.ca
Phone: (403) 262-0015 Fax: (403) 262-7383
email: cseg.office@shaw.ca

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RECORDER Committee



Chief Editor
Satinder Chopra
ARCIS Corporation
Phone: 403-605-0118
email: schopra@arcis.com



Associate Editor
Penny Colton
Exploritech Service Ltd.
Phone: 403-278-8755
email: penny@exploritech.com



Associate Editor
Marian Hanna
email: mhanna1@shaw.ca



Associate Editor
Gary Margrave
University of Calgary
Phone: 403-220-4606
email: margrave@ucalgary.ca



Associate Editor
Eric Andersen
Global Exploration Specialist Team
Phone: 403-237-1630
email: ecandersen@talisman-energy.com



Assistant Editor
Paul Anderson
Apache Canada Ltd.
Phone: 403-303-4736
email: Paul.Anderson@can.apachecorp.com



Assistant Editor
Joanna Cooper
University of Calgary
Phone: 403-220-2483
email: jkcooper@ucalgary.ca



Assistant Editor
Jonathan (Jon) Howlett
WesternGeco Canada
Phone: 403-509-4185
email: howlett1@calgary.westerngeco.slb.com



Assistant Editor
Kurt Wikel
Talisman Energy
Phone: 403-237-1615
email: KWIKEL@talisman-energy.com

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RECORDER

Official Publication of CSEG

Cover Photo: "Field trip season is almost here: Plain of Six Glaciers Trail, Lake Louise, Alberta. View towards the terminal moraine, the Victoria Glacier and Mount Victoria. Outcrop in the foreground is Lower Cambrian Gog Formation Quartzite. (Photo courtesy Martin Layzell.)

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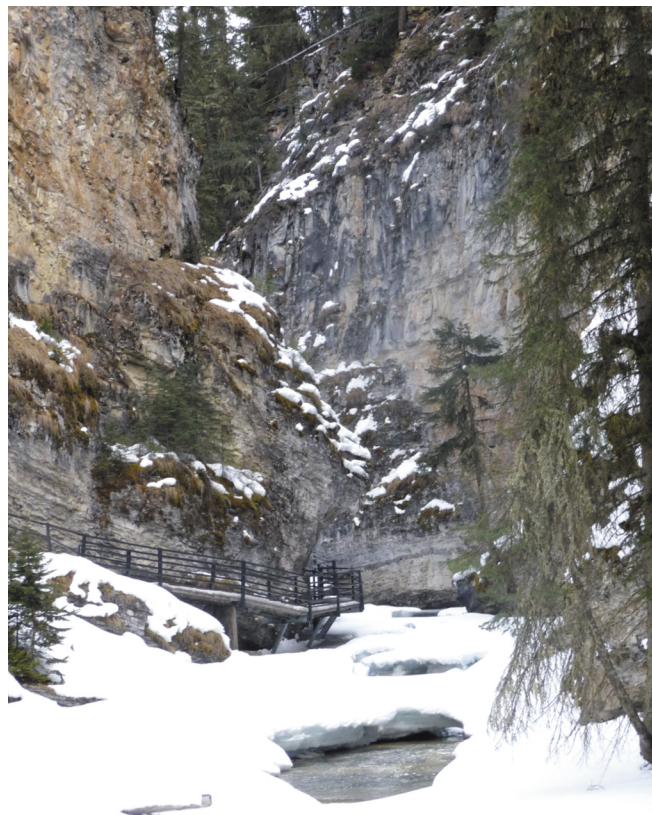
My first month as CSEG President has been interesting and a little busier than expected. Outside of the monthly meeting I've attended a CSEG Website committee meeting, a CSEG Foundation Meeting, and have had discussions with Jon Downton, Larry Herd and Laurie Ross. We are talking about our partnership with the CSPG so Jon and I have met with John Varsek and Graeme Bloy of the CSPG a few times, to talk about how to operate the joint annual convention.

I expect that the GeoCanada 2010 Convention will have passed by the time you read this article, so please share your thoughts on your 2010 Convention experience with me. I'd really appreciate your thoughts on our annual convention. Did you enjoy the opportunities to meet with your peers? Did you meet a few new people or see any long lost friends? Have you learned what you wanted to learn from the technical presentations? Were you impressed with the latest technologies in the exhibit hall?

Some of the societies involved in the 2010 convention have invited Larry Herd and me to attend their meetings in Calgary during the convention. Larry and I will learn about the activities and concerns of Earth Scientists from across Canada and from disciplines outside the oil and gas business. You can expect more on these topics in future columns.

Outside of the GeoCanada 2010 Convention (May 10-14), there are a lot of CSEG activities planned for this spring. I hope to see you at some of them. At the end of April I'll attend both the monthly luncheon and the SEG's DISC course. Unfortunately, I missed the April brown bag lunch and I'm not as up to date on curvelets as I'd like to be. I'll make this up by attending the May edition of the brown bag lunch. Just before the end of spring, I'll take a day off work to attend the T-Wave golf tourney at the Inglewood Golf Course. We live in Dover, just up the hill from the golf course, and we will probably finish off the evening of June 14th on my deck with a few fellow CSEG members.

This month's photo is from a spring walk in Johnston Canyon in Banff National Park. It is a pleasant and scenic 3km walk. My first time in the canyon left me wanting to do it again, but



Courtesy of Bernadette Nowak.

next time with a Geologist friend for company and elucidation. In the spring, ice crampons or studded shoe treads are essential as the paths are ice covered and without them you should wait for the ice to melt.

Spring is here and summer is around the corner. Lots of sunshine and longer days! It's my favorite time of year. Next time we meet I hope you notice my skin is a little darker and I'm a little fitter. I am looking forward meeting you at the CSEG events this spring. *R*

John Townsley

GeoCanada 2010 = CSEG's Annual Joint Convention

May 10-14, 2010 at the BMO Centre, Stampede Park, Calgary

Hosted by the CSPG, CSEG and CWLS with GAC, MAC, IAH-CNC, CCPG and CFES

Exhibits floor open for three days & Technical Program over four days

Earth Science for Society Exhibition (open to the public): May 10-11

CSEG Challenge Bowl – Canadian University Teams: Tuesday May 11

www.geocanada2010.ca www.cseg.ca



Happy May 2010! The theme of this executive message is community... just thought I would just spell it out for you all. It was after Peter Duncan's address at the March CSEG AGM where he won the 2009 Honorary Membership Award, and spoke about (and I will paraphrase a little) how great we have it here in Calgary and how our environment is unlike any other he has experienced, that I started to ponder what makes our community so unique.

I was wandering around the Plus 15s at lunchtime, and one of my colleagues commented on the number of people we recognized and greeted. It started me thinking about how interconnected we all are in the Calgary energy sector. Back in the 90s, there was the trivia game Six Degrees of Kevin Bacon, where virtually every actor could be linked to Kevin Bacon within six professional steps. I am thinking that everyone in the geophysical community in Calgary (and across Canada for that matter) could be linked through a maximum of four degrees of separation... we are a tight community that promotes active social and professional networks. I rather like that.

This May, we are fortunate to be holding the GeoCanada 2010 convention in conjunction with the CSPG, CWLS (and many others). This is our time to shine academically, professionally and socially. I would like to encourage you to support your compatriots as they present technical talks and posters, cheer on our students during the Challenge Bowl, support our Outreach committee as they bring "Earth Science for Society" to the public eye, and network with the over 4,500 attendees (including me!) during the Monday Night Mixer, Tuesday Networking Happy Hour and the Friday Core Meltdown. Take advantage of these opportunities!

As part of the Communications portfolio on the CSEG Executive, we (Cheran Mangat, my Assistant Director, and I)

are responsible for communicating these opportunities to you through our CSEG website and the RECORDER. Well, to be transparent, we oversee two rather wonderful committees who do the work, and we then report back to the Executive. A quick "shout out" to Satinder Chopra (ooh! "Four Degrees of Satinder Chopra"! Anyone? Anyone?), Penny Colton, Marian Hanna, Gary Margrave, John Logel, Jason Noble, Paul Anderson, Joanna Cooper, Jon Howlett, Eric Andersen, Kurt Wikel and Jim Racette who made the past year's RECORDER publications commendable in an economic downturn. I also have it on good authority that the first articles everyone reads are "Tracing the Industry" and "the Grapevine", so thanks to Carmen Swalwell and Lorna Engleson for keeping the gossip networks active and making our readers flip to the back of the magazine first. Corey Hooze is the backbone of our website (www.cseg.ca), and has taken it to the level we see today. Plans are in the works to make the website even more interactive going forward, and to streamline membership information and event registrations. A sincere thank you also to Carol Laws for her two years serving in the Communications role on the Executive: Cheran and I hope to continue moving forward as she has previously.

If anyone is interested in serving on any of the Communications' committees, please let Cheran or me know. We are fortunate in that we work with some of the most creative people in our industry, and are always looking for new talent and ideas.

In conclusion! Our community is unique because we have made it so, and continue to do so by encouraging each other to maintain our connectivity through social and professional networking both casually and through events sponsored by the CSEG. We should be proud of who we are, what we have achieved and what we represent... the future of our industry. *R*

Kristy Manchul
Director of Communications

MAY			
10-14	GeoCanada 2010 (CSEG's Annual Joint Convention)	Stampede Park Calgary	www.cseg.ca (or) www.geocanada2010.ca
10-11	<i>Earth Science for Society Exhibition</i>		
10	GeoCanada Luncheon: <i>Ray Zahab</i>		
11	<i>CSEG Challenge Bowl – for teams of University Students</i>		
12	GeoCanada Luncheon: <i>Brent Butt</i>		
JUNE			
14	CSEG T-Wave Golf Tournament	Calgary, AB	www.cseg.ca
15	Deadline for CSEG Student Scholarship Applications		
21	CSEG Technical Luncheon <i>Don Lawton (U of C): "Carbon capture and storage opportunities and challenges for geophysics"</i>	TCC, Calgary	www.cseg.ca
24	CSEG Student Industry Field Trip (SIFT)	Calgary, AB	www.cseg.ca
JULY			
18-22	SEG E&P – Abstract Deadline <i>CO₂ EOR and Sequestration (Abstract deadline March 31)</i>	Boston, MA	www.seg.org
AUGUST			
19-21	Doodlebug Golf Tournament	Jasper, AB	www.cspg.org

A recent incident in Ethiopia saw one employee killed in an attack on the recording crew. The security in place was breached and an armed attack occurred which resulted in a fatality of one of crew's employees. Two other individuals, a contract employee and a security officer, were injured in the ambush and are receiving medical care. This incident will likely be classified as some sort of domestic (localized) terrorism as that tends to be a bit of a catch-all these days. Of relevance to this column is the point that the local group likely responsible for the attack is a rebel group which has great concerns about the outsiders and have seemingly targeted this particular company's crew as they refer to "telemetry" on their website. The local rebels have espoused some concern that these outsiders are looking to enact brain control through telemetry.

This would seem the stuff of the local grocery store magazine – in our world. However in their world it may be that a perception becomes a reality they will kill for. Terrorism in many facets is often the simple struggle between the rich and the poor. I use the term "rich" and "poor" loosely. Rich would refer to our society in general (1st world nations). Poor would refer to third world nations. Terrorism is a term used by the rich when stopping these attacks. When the poor actually win (from time to time) and they write the history books – we call it revolution.

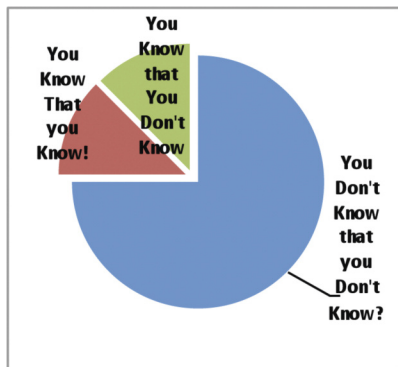
Twenty percent of the world's population uses eighty percent of the world's energy. Things we take for granted – single family house (heated and air conditioned), two or three cars, running water, hot water, readily access to food – are unfathomable to many in third world countries. Not only can they not contemplate it – they do not believe it exists somewhere in the world. Think of it in the following way:

From an article in January 2007 The RECORDER by Paul Thacker – Risk Management in Seismic Survey Design or "You Don't Know that You Don't Know?"

During a business management seminar many years ago, one of the authors was given an insight into human nature, an insight that has proven extremely useful during the design phase of our seismic surveys, something we know all about... right?

You Know That You Don't Know...

The seminar leader asked everyone to imagine a circle, a circle that held the Sum of Human Knowledge. He suggested that a group of technical specialists would understand some of this knowledge very well indeed and also would recognize several other disciplines where their degree of understanding was incomplete... right?



He represented these two areas of knowledge as small segments within the Sum of Human Knowledge and labeled them "you know that you know" and "you know that you don't know," as shown in Figure 1.

Figure 1. The Sum of Human Knowledge.

You Don't Know That You Don't Know?

After provocatively labeling the rest of the circle "You don't know that you don't know," the seminar leader outlined how some famous business failures had been the result of people being unaware that they were operating within this vast segment.

People taking flash photographs in a sports stadium at night should also fall into this category. Paraphrasing Kerekes (1998), "After all, they pushed the right button. What else is there... right?", which sums up perfectly the very essence of working in the "You don't know that you don't know" segment. The photograph of a floodlit stadium may serve as a memory trigger, but few can interpret the fuzzy, shadowy details to determine who actually kicked the ball. If the stadium lights went out, just how much value would a flash photo image have?

We absolutely face this paradigm as humans. We face it in our understandings of other cultures and them of us. We make assumptions that align with our knowledge base that are in some cases completely wrong in the face of another culture. Here at home many issues surrounding Aboriginal Consultation fall into this paradigm between Industry players and local Aboriginal representatives. This leads many (both sides) to say "Why can't they just be like us?"

I close this column off with something that all of us can understand more easily and align our thinking with. As an industry we all continue to struggle with the issues of safety and in particular ensuring we are reducing our incidents and getting our employees home safely every night. As we drill down into statistics some commonalities tend to show themselves – safety statistics for the youngest group (ages 18 to 25) are remarkably benign. We actually do a pretty good job with these new hires and if we can keep them from speeding they tend not to injure / kill themselves. (Call them the "You know that you don't know" group). And of course the oldest group (ages 45 and up) are very competent and take care of themselves generally (Call them "You know that you know" group). So often our biggest challenge lies in the middle age group (ages 26 to 44). They think they know and they may shortcut stuff that 99 % of the time goes right and 1 time out of a hundred goes terribly wrong (the "You don't know that you don't know" group). Hmmm – anyway just some food for thought for you! *R*

And on a totally unrelated matter...

From the Thursday Files

It's not something I'd plan your holidays on.
– Dave Phillips, *Environment Canada; Canadian spring forecast warm, dry*

Mike Doyle is the President of the CAGC – the Canadian Association of Geophysical Contractors – representing the business interests of the seismic industry within Canada. The CAGC website may be found at www.cagc.ca



"You are making a great contribution to society..."

*An
interview
with
John Boyd*



John Boyd is one of Calgary's most respected geophysicists, known for his efforts and accomplishments on many fronts – technical, business, and community most notably. He has been active in the industry since 1960, and remains one of the CSEG's most dynamic and vibrant members. While now semi-retired, John continues to learn and employ new techniques doing project work for the company he founded. He can also always be counted on to volunteer his support for both industry society efforts, and those helping the community at large.

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"You are making a great contribution to society..."

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RECORDER editors Satinder Chopra and Eric Andersen recently met with John and conducted the following interview.

(Photos courtesy: Joyce Au)

S: *John, let's begin by asking you about your educational qualifications and your work background.*

J: I graduated from the University of Toronto in 1960 with a geophysics option in Engineering Physics. Two people that I studied under were Tuzo Wilson and Fraser Grant, both important names in geophysics. It was fun because – and this was a couple of years after the International Geophysical year – when we had a lecture from Tuzo he would start off talking about geophysics or continental drift and then in the next moment he might be talking about his ride in the Trans-Siberian Railroad from Russia to China or some other adventure from the IGY.

S: *Can you also mention something about your work experience?*

J: I had had one summer working in mining geophysics up in Northern Ontario and Northern Quebec, and I liked that but I decided that I would look for a job in the Oil Industry so I could compare them. There weren't a lot of jobs in 1960 but I was lucky enough to get hired on by Pan American Petroleum who changed their name to Amoco a few years later. I started with Pan American in Edmonton, then was moved to Calgary. I worked there for about six years and then left to join a small consulting firm. After that I worked for a contractor for a couple of years, and then I joined IBM. I joined Digitech in 1970 and I was there until I

left in 1977. I guess you could say that I was rattling around quite a bit in those years!

S: *Didn't you form your own consulting firm?*

J: Yes, in 1977.

E: *The change from Amoco / Pan American to IBM, that's interesting.*

J: Yes, but there were two steps in between. The consulting company that I worked for had an interest in a new company called CDP (Computer Data Processors) and they were one of the very early companies trying to move into digital processing of seismic data. I had some experience processing with GSI in 1966 (they were the only commercial digital seismic processors

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"You are making a great contribution to society..."

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((L-R): John Boyd, Satinder Chopra and Eric Andersen.

at that time) and I was assigned to be our contact with CDP. I used to go over to their office and talk to a young engineer by the name of Dave Robson who was about my age, and Dave and I did a lot of things together, there and later at Digitech. Dave went on to a small processing company called Veritas and turned it into one of the major geophysical companies in the world. I did a lot of work with processing in those early years and I knew some people at IBM and I ended up there for a couple of years doing development work and sales work. Then I moved to Digitech because I knew Ben Berg from Amoco who had started the company and they were going to open an office in Australia. I thought, "I'll go for that," and I joined Digitech. So it wasn't a direct jump from Amoco to IBM, there were some steps in between.

S: *You joined Amoco in 1960 and stayed there for about six years time; were you engaged in exploration projects interpreting seismic data?*

J: Yes, I was, it was basically interpretation and field work. With Amoco in those days you spent a lot of time in the field, especially in the first couple of years. It was fun, in my first winter in the field we were actually interpreting data in a crew office. That was probably the last time that happened

because the analog processing centres were just coming into their own. Geophysicists stopped interpreting paper records in the field because they could work with processed seismic sections in town. Anyway, there were four geophysicists on the crew, we slept and worked in a trailer with a diesel furnace that kept cutting in and out. Ralph Lundberg and I used to pick first breaks and work out weathering corrections and there were two senior geophysicists interpreting a Slave Point play on monitor records. We picked locations for a slim hole rig to drill and log holes to verify structure. I think that's probably the last time anyone at Pan American ever did that kind of a field interpretation and I might be one of the few people still working in Calgary who has been part of one.

The following winter I was a bird-dog on a crew in Fort Nelson and I also used to pick reflections on paper records to compute static corrections for the analog processing centre back in Edmonton.

Then I started to interpret data and we had a major exploration effort in the Devonian. So, over a period of a few years, we essentially covered the ground from Grand Prairie to Hinton with a grid of seismic lines about two miles by two miles and we would then

infill with more detail if we found any Leduc anomalies. We made some good discoveries and I worked on that project for a few years. And then Rainbow Lake was discovered and it was a major geophysical success that suddenly created a boom in the industry and that's when I got kind of lured away to join a consulting group in 1966.

S: *So you spent a long time with Digitech and then moved on to the consulting company?*

J: I went to Australia with Digitech for six months in the autumn of 1970. They closed the office in Australia and I went over to start up an office in London in September of 1971. We had a contract with BP who had the same type of computer and software that Digitech had, so we had a group in BP's office contracted to do processing input, primarily marine processing. I did that for a couple of years with BP and then saw the opportunity to set up our own processing centre in London which ran for several years. In 1976 the decision was made to close it down because there was a downturn in activity in both Calgary and London and we couldn't keep both centres going. So I came back to Canada in the summer of 1976. I enjoyed working in Australia and England and in the North Sea. The work was fascinating

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"You are making a great contribution to society..."*Continued from Page 12*

and you will appreciate this Satinder, you get more of a global look when you move around the world and I have always treasured that. It was good for me.

S: *Now I was going to ask you – you started your own company in 1977. How did that idea of starting your own consulting company first come about, and then what were the initial hurdles that you faced?*

J: There were a couple of things. I wanted to get back into interpretation, I thought that the years that I spent in processing were extremely useful and would help me in consulting. I wanted to be an interpreter again and I wanted to start my own business. I talked it over with my wife – we had three small children then – and she said, "Go for it, you can make it work," and so I did. The hurdles, well it was somewhat slow starting up because the activity level wasn't very high and I was a bit out of touch with the Calgary market after being away for five years, although I knew a lot of people. The fact is that when I left Digitech to start consulting I had absolutely no work lined up. I thought that it wasn't ethical to go looking for work for myself when I was working for somebody else. But quite quickly I found a few things to work on. My wife laughs about the first morning that I was on my own. I got up and put my suit on and she said, "Why are you putting your suit on, what have you got to do?" I said, "Well something will show up, something will happen," and it did. In that first year I grossed less money than I made net on salary the year before, but it kept building. I was also lucky that I started soon before the West Pembina discovery which created a leap in activity.

S: *Do you have any advice for young entrepreneurs in terms of what they should be looking out for or keeping in mind when they start their own businesses?*

J: Well, if you are a young geophysicist starting your own business

you should remember a couple of things. You have to stay technically competent and you will no longer have courses put on or organized by your employer, so you will have to attend the conventions, take the Doodle Train courses and all that sort of thing. It is vitally important because if you don't you become obsolete. You also have to remember that you are in the service

industry so you had better give good work and good service to your clients or you won't stick around. You should appreciate the geophysical industry because you are part of it – data brokers, processors, contractors and consultants, and oil company geophysicists. One of the things I love about the geophysical business here is that all these people work together so

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"You are making a great contribution to society..."

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nicely and so you get into that loop where you work with clients and competitors and it all seems to work.

E: *Nowadays new grads go directly into one specialized aspect of geophysics, either at an oil company or a service company, and the diversity of training isn't the same as it was years ago. When you were working your way up, you went from picking field monitors, to bird-dogging, to processing, to interpretation and so on. Do you feel we've lost something as an industry?*

J: Picking monitor records in the field is not really important, just an interesting piece of history! I probably had a better field background than most young geophysicists today and I think that was good but, by and large, the geophysicists today are better trained and more quickly trained than they were in my day. I mean, where I was after six years, I think the average young person is probably there in two or three years today. There is a lot more to the science and profession than there used to be.

S: *At this stage in your life, you can look back on your life and a quite illustrious career. Do you get a sense of satisfaction, a sense of fulfillment, or is it something else?*

J: I can look back and I can say that I helped to build Boyd PetroSearch into a great company, and really there were three of us who built it. Larry Herd and Neil Thompson and I were the ones that made the moves and put it together, so I have a lot of satisfaction about that. I have satisfaction about what I have done with APEGGA and CSEG and the community work that I have done. I also have regrets at times, and we probably all do, that sometimes we are so busy that we don't spend as much time with our families as we'd like to. That's a regret. There are some interesting things that I did that I'm proud of. I know somebody asked me once, "What important contributions have you made to the geophysical business in Calgary?" Well, one of the great contributions I feel I made was when I was Chairman of a committee to select the second Chair in Geophysics at the University of Calgary and we recommended Rob

Stewart. He was not well known and he was not the first choice of the University people, but we picked him and so I often say that one of my great contributions is helping to bring in Rob Stewart – just look at the things that Rob has contributed to geophysics in Calgary. I kind of got a kick out of that.

S: *John, what are you looking forward to now, what is your goal?*

J: I am semi-retired. I am still on the Board of Boyd PetroSearch along with Neil Thompson and Larry Herd. I am also on the Boards of a couple of junior oil companies. I do a little bit of consulting work because I enjoy the technical part – and the business – of geophysics. I don't know how long I will do that. I stepped down as president of PetroSearch at the end of 2006 and Larry Herd is running the company now and taking it to new heights. I still look forward to still having an association with the industry, I look forward to the community work that I do. I have lots of other interests.

S: *I was going to ask you to name a few of the landmarks in your career.*

J: Landmarks!

S: *Successful landmarks.*

J: Well, when I started consulting in 1977 there were some things I wanted to do differently. The consulting business is primarily made up of one person shops, and they do very, very good work. I wanted to build an organization that would outlast me. I also wanted to develop some product rather than just do consulting by the hour, so one of the landmark decisions that I made was when I saw an opportunity to get into the synthetic seismogram and forward modelling market. I retained some people to write some software for me and hired Dave Normandeau – who was my first employee; the second was Larry Herd and the third was Neil Thompson. This was in about 1980, so I made a move early on to grow and the growing wasn't a power move, it was to build something that would last. So that was kind of a landmark, the first staff that I hired.



Then, a landmark decision was taken at geophysics in the potash industry. We had an enquiry and the three of us sat down and we decided that we'd send Larry, so Larry drove to Saskatchewan because we couldn't afford airline tickets and we got some project work. That started it, more than twenty years ago, and it has turned into a very important niche business for the company, so that was a real landmark event.

S: *Tell us about the Saskatchewan potash mining industry – why is it important, how much potash is produced and consumed in Canada and so on?*

J: Well, it's a huge industry and there are three producing companies, with others coming in. Most of it is exported, a lot of it interestingly enough to China. The Chinese think red is a lucky colour, so they love our red potash! You see the CanPotex trains headed to the West Coast and it is a very important export and Canada is the world's leading producer. I don't know what the production is or what the dollar volume is, but it's huge and it's huge for Saskatchewan.

S: *Tell us of how your work helped in the exploration for potash.*

J: It's not exploration, it's development. We know where the potash is. There have been enough test holes drilled through the Prairie Evaporite to tell us where the potash is present. It is a thin layer of potash in a very thick evaporite sequence, but it is present over a very large area. The interesting thing is the contrast between mining development and petroleum exploration. Oil and gas is usually trapped in local anomalies rather than being regionally present. We run our seismic surveys

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"You are making..."*Continued from Page 14*

looking for anomalies because oil and gas migrates into anomalous geological features whether they be reefs or anticlines or buried channels. Mining engineers hate anomalies. Abrupt changes in rock type or interruptions at the mine level are major problems. What we have done historically, and got better and better at, is look at the ground before it is mined and predict changes or problems at the mine level. The Prairie Evaporite can be unstable and there are collapse features – areas of salt dissolution – and these things are hugely disruptive for mining equipment.

We started with reconnaissance 2D seismic and then we went to closely spaced 2D lines and then sometime in the early 90s moved into 3D. There isn't enough impedance contrast to differentiate potash from halite, but you can detect some impurities in the potash from their density contrast, so we are getting to the point where we are using inversion and things like that to improve our interpretation.

E: *That's interesting John, would you say that your potash work got you into various high resolution techniques well before the rest of the industry?*

J: Yes, that's a good point Eric, perhaps. It's probably partly because of the subtle differences or changes we need to go after, and partly because a lot of Saskatchewan has very good near surface conditions for seismic, so we get the necessary high frequencies. We are shooting in good solid clay, not much sand on the surface, so it's beautiful data. With some exceptions we measure frequencies up into the 200 Hz range.

S: *John, with five decades of experience under your belt, can you give us your perspective on the many technical changes and advances you've seen in your career?*

J: Well, I told you about the first interpretations that I did in an

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uncomfortable trailer up in the Caribou Mountains. I can also remember the first 3D that we did. It was in 1986 or 1987 and it was a small 3D, I think it was two square miles. We didn't have a workstation and what we did now seems ridiculous. We had the processor play out each inline on paper, we picked those things manually, and then we had the picks digitized. It took weeks to interpret that little 3D. In contrast – I was thinking about this the other day – two weeks ago I was filling in for one of our geophysicists who was away on holidays. He had a 3D coming in with a drilling commitment on it, and it was a similar size, a couple of square miles, but it was in an area of complex geology in the Mannville Section. Anyway I got that 3D on Tuesday morning and the client was scheduled to come in at 8:00 a.m. the next day to pick two well locations. I put in a solid day and worked until about 7:00 p.m. in the evening. I knew that I didn't have all the answers because I didn't have time to address all of the subtleties, but I had enough to pick two well locations which, incidentally, have been drilled and they came in.

Another thing I laugh about is remembering when we were sitting around many years ago and we were saying, "We have to buy a workstation," and then one of us, probably me, was saying, "What's going to happen if we spend all this money on a workstation so that we can do everything a lot faster so we bill less and it will actually reduce our revenue?" But of course it didn't! It allowed us to see more and do more, and in the end we spent more

time at a much higher level digging deeper into the data. We have always invested in technology and now we can do things with data that we could only dream about.

I can remember at Amoco actually doing an amplitude study on the Cardium. We did it – not with paper records in the field because by now we were into analog playbacks, so we used dividers and measured peak-to-trough deflection in millimeters and wrote the numbers on the map. When you think what you can do now with attributes it seems funny! These are the changes that I have seen, and they seem to come in jumps. 3D was a tremendous jump and the concept of an interpretive workstation was too, although the first ones didn't do as much – some of the early ones were mostly just pickers but that concept of using a computer to help you interpret was a big forward leap.

S: *John, what kind of advancements do you think we can expect in geophysics?*

J: Well I think a lot of the improvements are going to be in the field. Look at wide azimuth marine acquisition for example, that's a huge leap because the marine 3Ds suffered from good azimuth and offset distribution in one direction and poor in another. You know, we are approaching the concept of recording the data on every geophone. It's going to happen and in fact there is a really good article in the RECORDER that came out last week from CREWES. [Editor's note: see March 2010 issue.] Did you see that Satinder?

They demonstrated in a field experiment that if you have even a short array, say 20 metres long, you start to alias surface waves and once that happens, you can't properly recover all of the data.

I think we are close to going as far as we can with imaging. We seem to be able to handle the really tough problems, like sub salt structures. I don't think there will be further major improvements in imaging. I think there will be improvements in attribute work. I think there will be improvements in the three component area, which is something you know I

am very interested in. I think there will be some breakthroughs in micro-seismic and passive seismic measurements. So there will be good things, lots of good things.

S: *I look forward to many of these. John, apart from the huge accomplishments that you have to your credit and there are a number of presentations that you made, I see on the publication side it has been rather slow.*

J: I've been lazy. I have presented many times, primarily to the CSEG and the EAGE, and I tended not to write them up. There have been times that I have been asked to publish and I didn't, so I have not been very good that way Satinder.

S: *But people with your knowledge and experience should write...*

E: *John seems to like back seat driving – he supports a lot of people who write and present!*

J: Let's change the topic! You know I have always been interested in 3C work. Back in 1987 we organized a shoot in the Carrot Creek Area. We did two 3C lines over conglomerate bars, and it was successful and many companies joined in. Some companies didn't join because they didn't believe we could actually generate a shear wave from a P-wave source, but it was a good experiment. Then of course we donated the data to CREWES and they did good work with it. The Blackfoot 3C 3D happened because the U of C came to us and asked if we would help organize a symposium where we would invite companies to present their ideas on a good test area for a 3D 3C survey. We had half a dozen submissions and Blackfoot was chosen because it was interesting geologically, it was close to Calgary, and it was in an area that was easy to operate in. The data was good, it was an interesting experiment, and it provided some useful data to CREWES.

Now I am working on a 3C 4D, a time lapse measurement of two 3C, 3D surveys, and it's fascinating. I am finding that there are things that the converted waves are showing that the

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"You are making a great contribution to society..."*Continued from Page 16*

P-wave doesn't show, and I think this is wonderful. We all realize that the resolving power of shear wave data is much less than P-wave data – the wave lengths are much longer, and it's noisier. But the fact that rocks respond differently to pressure waves and shear waves means that there will be differences, and it's those differences that you are looking for. It's not the ability of shear waves to resolve small things that's important, it's their ability to respond differently to changes in the subsurface, and we are seeing examples of that. Kind of neat.

S: *That's the way they use multicomponent data in areas where they have gas plumes.*

J: Gas plumes, yes, exactly, just a beautiful example. Some of those examples in the North Sea are fascinating.

E: *You have received a lot of awards John, from the CSEG and APEGGA and such. I was just curious to know*

how you feel about getting these awards, and which ones you treasure the most?

J: Well I have always wanted to give back to the industry, so I have supported the CSEG and APEGGA, and I think they are both wonderful organizations. CSEG I think is a brilliant organization because when you consider what the CSEG does with the paid staff of two people in terms of putting on conventions and courses and Doodlebug golf tournaments – it's wonderful. The CSEG to me also epitomized what I was talking about earlier – this relationship we have between service companies of all types and oil companies.

We have a great advantage over the geologists –there isn't a geological industry comparable to the geophysical industry. We have this great mix of the service side and the oil company side and I think it makes the industry very special.



Getting the CSEG Medal was a great honour for me. The year that I handled honours and awards I was approached by an anonymous donor who suggested the award and funded its design and production. I presented the idea to the CSEG executive, and we gave the first medal to Roy Lindseth. Quite a few years later, I received it, so that was very special.

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And then the Charlesworth Professional Service Award from APEGGA, which recognizes service to the professions, was special. I have been involved with APEGGA for many years and it meant a great deal to me to receive that award.

S: *Good job. John, one advantage of communication, especially written, is that your experiences can serve to inspire others. You have a wealth of experience, 5 decades, so we were just wondering if you ever have toyed with the idea of writing your memoirs.*

J: Well, I just told you I didn't write much, but you keep coming back to it (laughter and mixed talk).

S: *Now at this stage in your life you might think of—*

J: Well I might think about it. You know I have done a few things. I was looking recently through some of my stuff and I found a diary of my – I think it was my third trip to China – and it was an interesting trip because I was doing field work in a remote area of China and I got sick and it was difficult. I kept this daily diary and it was fun to read it after many years. Yes, there are a few things like that I could do.

S: *My suggestion here is give it a serious thought.*

J: Yes, I can give it a serious thought.

E: *Apart from the science and the business, what other interests do you have?*

J: On the community side I have been a member of the Rotary Club of Calgary for many years. I was President of it back in 2001. It is a great organization – does great things in the community, raises a lot of money, and spends it wisely here and internationally. I am a skier and a hiker in the summer time; I am a bad golfer. I go sailing every year with a bunch of geophysicists and we call ourselves the Doodle Buoys. There is a Doodlebug and a Doodle Train and



((L-R): Satinder Chopra, Eric Andersen and John Boyd.

a Doodlespiel.....well, we are the Doodle Buoys. I have become determined to improve my French, you know, to learn to speak French reasonably well, so actually I have taken a run at that in the last few of years by taking courses at the Alliance Française, and I am progressing.

I was involved in this International Year of Planet Earth, which was a three-year joint initiative of UNESCO and the International Union of Geological Sciences to promote the concept of Earth Sciences for Society. I was Canadian Chairman of that and started in the fall of 2006 and I am almost wrapping it up here in the spring of 2010. We've done some interesting things; we've done some good outreach activities. I've learned a lot and attended meetings in Paris and Lisbon and San Francisco. I read a lot, I like the Theatre – I do lots of things.

S: *Eric, you know Oliver has labeled this last question the "Satinder Question". Why don't you ask it this time?*

E: *John, what would your message be for young entrants to geophysics? What are the rewarding aspects of taking up a career in geophysics?*

J: Let's assume that we are talking about people that are in the oil and gas industry, I'd say get as broad knowledge as you can. Try to learn something about reservoir engineering, drilling, and of course a lot of geology. As well, make sure you always keep your geophysical skills as high leveled as you can, by taking courses, going to conventions – you need a broad knowledge to be a good geophysicist. Certainly you need an appreciation for the problems that a reservoir engineer has, you have to have that. The reward is the satisfaction you can get from being part of an industry that discovers and develops earth resources – and the excitement of success. That would be my advice – learn a broad spectrum of knowledge and be aware of the fact that you are making a great contribution to society in the work that you do.

S: *Wonderful. John, thank you very much for giving us this opportunity to sit down and chat with you. It's been a pleasure. R*

Case Study

Shear-wave sourced 3-D VSP Depth Imaging of Tight Gas Sandstones in Rulison Field, Colorado

Prajnaji Mazumdar and Thomas L. Davis

Department of Geophysics, Colorado School of Mines, Colorado, USA

Introduction

Rulison Field, Piceance Basin, Colorado was approved for development drilling to 10-acre spacing in 2003. The down spacing and hydraulic fracturing within this unconventional reservoir has increased its production five fold in less than a decade. A significant portion of the gas production is from low permeability fluvial discontinuous sandstones within the Williams Fork Formation of the Mesaverde Group. The gas is generated in the thick thermally mature coals of the Cameo Coal interval within the lower part of the Williams Fork Formation and migrates through the natural fractures that connect the reservoir and the coal interval. Development of this reservoir section is a challenge because the sandstone reservoir bodies are thin, generally below resolution of conventional compressional-wave (P-wave) seismic data, and lack acoustic impedance contrast with the surrounding shales. However, these sandstone bodies have a shear-wave impedance contrast with the encasing shale and that is what potentially makes shear waves attractive for imaging of these productive sand bodies.

To test the value of shear waves in imaging tight gas sands we conducted a 3-D VSP survey in Rulison and applied anisotropic Kirchhoff 3-D prestack depth migration to the data. A geologically-constrained migration-velocity model was created by integrating the results from the virtual source method, well logs, interval velocity derived from surface seismic and the Dix-differentiation of the fast (S^H) and slow (S^L) shear-wave NMO ellipses. The resulting common image gathers (CIG) are flat, indicating that the reflection events can be stacked reliably. Moreover the productive sand bodies have been reliably imaged with this technique.

A Brief Background of Shear-wave Tight-gas Sand Exploration

In spite of its abundance, natural gas in Rulison Field is difficult to extract economically. P-wave (compressional wave) surface seismic imaging of reservoir units is impossible. Also, fracture detection within the sandstone intervals from P-wave data is not feasible. While none of the wells in Rulison Field are dry the potential for these wells to become uneconomic exists as gas prices fall below \$5/mcf. As the reservoir has not been imaged adequately with conventional seismic methods operator drill wells at a spacing interval that allows them to adequately drain the reservoir (a 10-acre spacing in Rulison). The sandstone intervals in the drilled wells are identified from lithology indicator logs, eg. Gamma ray (GR) logs, and the sandstone intervals are hydraulically fractured.

A limited number of case studies have been published on imaging formations with low P-impedance contrast. The VSP shear-wave imaging case studies have mostly been done in low acoustic impedance contrast formations using P-S data (Nazar & Lawton, 1993; Roche et al., 2005; MacLeod et al. 1999; Macrides & Kelamis, 2000; VanDok & Gaiser, 2001; Rampton (1995); Michelena et al. (2001)). Hokstad et al. (1998) used reverse-time migration on the signatures recorded by horizontal geophones in a walkaway VSP survey in an offshore environment and found that the shear-wave migration was noisy (because of limited available migration aperture) yet with better resolution (attributed to short wavelength of shear waves in their study). A case study with PS VSP imaging, particularly for tight sand detection has been documented by O'Brien & Harris (2006). They succeeded in using walkaway VSP data to image the sandstone bodies in the low porosity Bossier and Cotton Valley sands in East Texas Basin. They did 2-D imaging and concluded that PS waves are sufficient to image the sandstones in their area of study. To the best of our knowledge, a 3-D non-converted shear-wave VSP depth imaging case study of tight gas sands is neither available in literature nor reported in industry. In this paper we would use shear-wave sourced VSP shot records to detect the *elusive* sandstones.

VSP Data Acquisition at Rulison

The Reservoir Characterization Project at Colorado School of Mines acquired a 3-D, multi-component VSP survey in 2006.

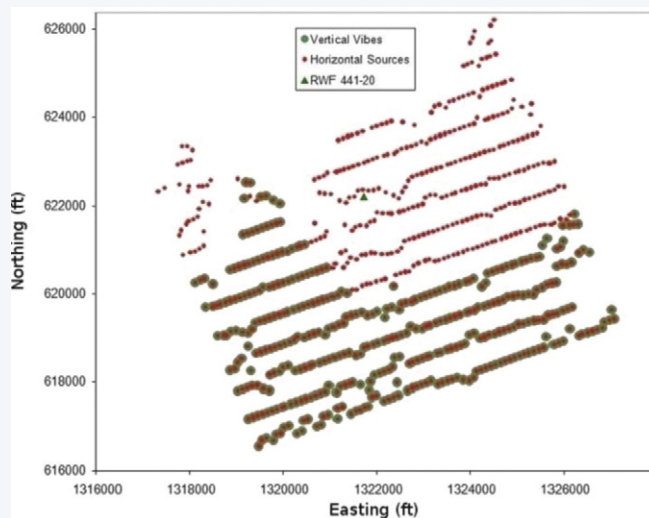


Figure 1. Map showing the shot locations (red dots for horizontal vibes and green dots for vertical vibes) and the location of the well RWF 441-20 (green triangle) that the VSP array was installed in during the survey.

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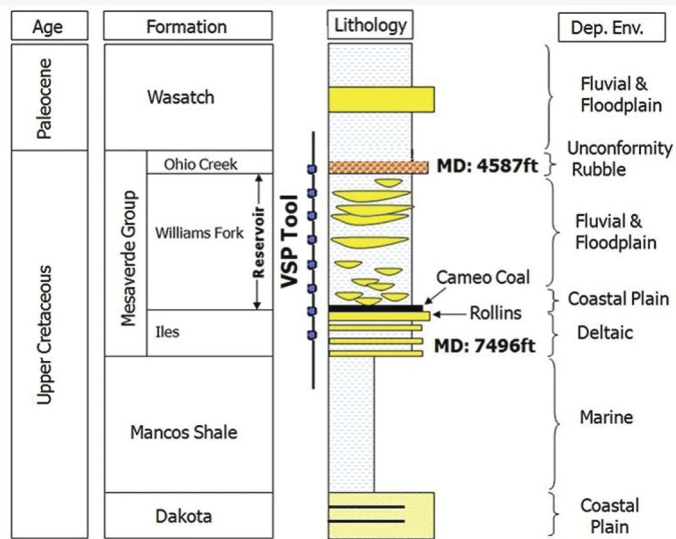


Figure 2. VSP tool layout in Rulison Survey (Courtesy: Williams Production Co.).

The VSP survey was a part of a project for integrated characterization and monitoring of Rulison field using surface seismic, VSP, geomechanics, well logs and production data. Two horizontal vibrator trucks were used as seismic sources that generated two mutually orthogonal horizontal ground motions at each of the 700 shot points. One horizontal vibrator was oriented at N70E direction and the other horizontal vibrator was oriented at N20W direction. In addition, a vertical vibrator was operated at about 300 far-offset shot points. The surface locations of the horizontal and vertical vibrators are shown in Figure 1. The 3C geophones (one vertical and two horizontal) occupied 60 levels in the borehole.

The shallowest 3C receiver is located at the top of the Williams Fork Formation (at 4587 ft) and the deepest receiver is within the Cameo Coal (at 7496 ft) as shown in Figure 2. The receiver spacing in the array is 50 ft. Table 1 details the source parameters in the Rulison VSP survey in 2006.

Parameters	Vertical Vibrator	Horizontal Vibrator
Model	AHV-4	M18 (Mertz)
Number of Vibes	1	1
Start Frequency	6 Hz	5 Hz
End Frequency	120 Hz	50 Hz
Start Taper	300 ms	300 ms
End Taper	300 ms	300 ms
Sweep Type	Linear	Linear
Listen Time	5 s	6s
Sweep Length	10 s	10 s
Number of sweeps	6	6
Sample Rate	2 ms	2 ms
Source Points	300	700

Table 1. Source and receiver parameters.

Shear Wave VSP Imaging of Sandstones

Subsurface imaging is done using a migration procedure that takes seismic wavefields recorded either on the surface or in a borehole as input and computes the location and reflection strength of subsurface interfaces. There are various ways to

migrate the input seismic wavefield. A popular method, Kirchhoff migration, is used in this study. Next we describe the fundamental steps we used in this study to image the subsurface using non-converted shear wave VSP data. These steps include-

1. Anisotropic velocity model building (for migration), and
2. Computation of traveltimes and Prestack Kirchhoff depth migration.

In Rulison Field, gas production comes mainly from sandstone beds that are fractured. Shear waves travelling through fractured sandstones split into fast and slow modes. The fast shear wave is polarized parallel to the fracture plane and the slow shear wave is polarized perpendicular to the fracture plane. The procedure to separate the shear waves for all the acquired shots is discussed in Mazumdar and Davis, 2009. In this section, we would discuss how to use the transmitted split shear waves for anisotropy parameter estimation and build an approximate velocity macro-model needed for depth migration of the reflected split shear waves. Next, we migrate the shear wave VSP dataset using the macro-velocity model to recover the image of the subsurface. The interpretation of the shear wave images is outside the scope of this paper and shall be discussed in a sequel paper.

The azimuthal variation of normal moveout velocity for non-converted modes is described by an ellipse in the horizontal plane (Grechka & Tsvankin, 1998). In this study a hyperbolic moveout approximation is used that accurately describes the traveltimes variation with offset. The maximum offset to depth ratio in the Rulison VSP dataset is about 1.4 for the shallowest geophone (measured depth = 4587 ft) and about 0.86 for the deepest (measured depth = 7500 ft). All the shot points on the surface were chosen for the purpose of inversion. Finally, the traveltimes needs to be described by a Taylor-series expansion for squared traveltimes $t^2(x_\alpha^2)$ where x_α is the offset of a source point on a survey line at an azimuth of α . The Taylor-series expansion can also breakdown for shear waves in certain anisotropic media where it can lead to cusps on traveltimes curves. However, the cusp will occur only if the anisotropy is sufficiently strong (Helbig, 1966; Musgrave, 1970) even in a homogeneous medium. The cusps do not occur in the Rulison dataset because it requires the value of $\sigma^{(V)}$ be greater than 0.6 and the source-receiver offsets greater than 4.5 kms.

In Rulison Field, both the overburden and the reservoir interval are anisotropic. The overburden as well as the reservoir interval contributes to the shear wave splitting. The reservoir rocks in the Williams Fork Formation splits the incident shear waves due to the presence of natural fractures in the rocks (Matesic, 2007).

We use the following equation (Grechka & Tsvankin, 1999) to estimate the interval NMO ellipse:

$$W_l^{-1} = \frac{\tau(l)W^{-1}(l) - \tau(l-1)W^{-1}(l-1)}{\tau(l) - \tau(l-1)} \quad (1)$$

where W_l is the interval ellipse in the l -th layer, $W(l)$ is the effective NMO ellipse in the bottom of the l -th layer, $\tau(l)$ is the zero-offset traveltimes to the bottom of the l -th layer. In the case of horizontal reflectors it is straightforward to use Dix-type equation 1 to estimate the interval NMO ellipse. Within the RCP

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survey area, the maximum dip is less than 2 degrees. Thus the dips in the reservoir interval do not affect the azimuthal velocity analysis in the RCP survey area. The azimuthal NMO can also be influenced by lateral velocity variation (Grechka & Tsvankin, 1999). Also, the lateral velocity variation is investigated within the RCP survey area. The dipole sonic logs at various wells in RCP survey area show that the shear wave vertical velocity trend does not vary significantly in the survey region. Moreover, a time slice taken at 2000 ms (within the reservoir interval) shows that there is mild lateral velocity variation. In the RCP survey area we see that the lateral velocity variation is small (see Figure 3). The rate of lateral velocity variation shall be even smaller than the magnitude of lateral velocity variation. Hence, we have not attempted to remove the effect of lateral velocity variation.

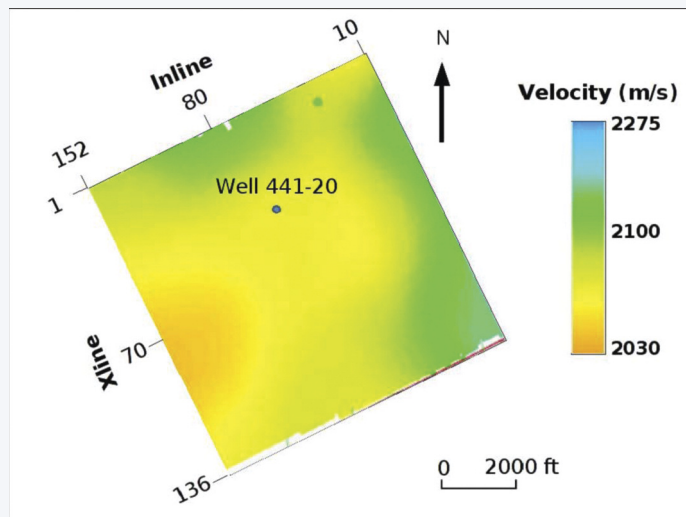


Figure 3. Shear wave RMS velocity time slice at 2000 ms (within the reservoir interval in Williams Fork Formation).

The reservoir interval is divided into smaller depth intervals and the inversion is conducted at each layer. For example, the reservoir interval is divided into three pseudo-layers (irrespective of the evidence of any spatially continuous geologic reflector) of 1500 ft each and the Dix-type differentiation is conducted to estimate the interval velocities at each sub-layer. The procedure is repeated with smaller depth intervals, say, three pseudo-layers, each with thickness of 1000 ft. We get comparable results from the Dix-differentiation procedure for both the cases of 3 pseudo-layers and 4 pseudo-layers. The interval velocities of fast and slow shear modes are obtained by constructing the matrix W_{ij} for different depth locations of geophones. Then the matrix W_{ij} is inverted and used in equation 1. This gives us the interval W_{ij}^{-1} (I) which is inverted to get interval W_{ij} for the I -th layer. Finally, the interval NMO velocity ellipses for the fast and slow modes and their orientation can be computed from the coefficients of the inverted matrix, W_{ij} . The next section explains how azimuthally dependent NMO velocities can be used for anisotropy parameter estimation in the reservoir section. Because the reservoir rocks are fractured we assume HTI media.

Azimuthal Dependence of NMO Velocity in Reservoir Section

The general NMO equation for a horizontal HTI layer that fully honors the 3D behavior of phase- and group-velocity vectors is described by Tsvankin, 1997. The azimuthal dependence of NMO velocity for a non-converted mode is expressed as:

$$V_{NMO}^2 = V_{vert}^2 \frac{1 + A}{1 + A \sin^2 \alpha}, \quad (2)$$

where α is the angle between the survey line and the symmetry axis, and A is an anisotropic term given by:

$$A[P - wave] = 2\delta^{(V)} \quad (3)$$

$$A[S^\perp - wave] = 2\sigma^{(V)} \quad (4)$$

$$A[S^\parallel - wave] = 2\gamma^{(V)} \quad (5)$$

Equations 3 to 5 show that the azimuthal dependence (also valid outside the symmetry planes) of NMO velocity for all the three non-converted wave modes can be expressed through Thomsen parameters of the equivalent VTI medium. The NMO velocity contains just three unknowns. We require measurement of NMO velocity on at least three different azimuthal angles (Rüger & Tsvankin, 1997). The resulting NMO velocity can be inverted for the vertical velocity, the axis orientation, and the parameter A for any given pure mode. Here all the shots have been used for estimation of these three Thomsen-style parameters. Also,

$$V_{NMO}(\alpha = 90^\circ) = V_{vert} \quad (6)$$

$$V_{NMO}^2(\alpha = 0^\circ) = V_{vert}^2(1 + A) \quad (7)$$

The exact NMO velocity in the symmetry-axis plane for the P , $S^\parallel$ and $S^\perp$ modes (Tsvankin, 1997) is given by:

$$V_{P,NMO}(\alpha = 0) = V_{Pvert} \sqrt{1 + 2\delta^{(V)}} \quad (8)$$

$$V_{S^\parallel,NMO}(\alpha = 0) = V_{S^\parallel vert} \sqrt{1 + 2\gamma^{(V)}} \quad (9)$$

$$V_{S^\perp,NMO}(\alpha = 0) = V_{S^\perp vert} \sqrt{1 + 2\sigma^{(V)}} \quad (10)$$

where
$$\sigma^{(V)} = \left(\frac{V_{Pvert}}{V_{S^\perp vert}} \right)^2 [\epsilon^{(V)} - \delta^{(V)}]$$

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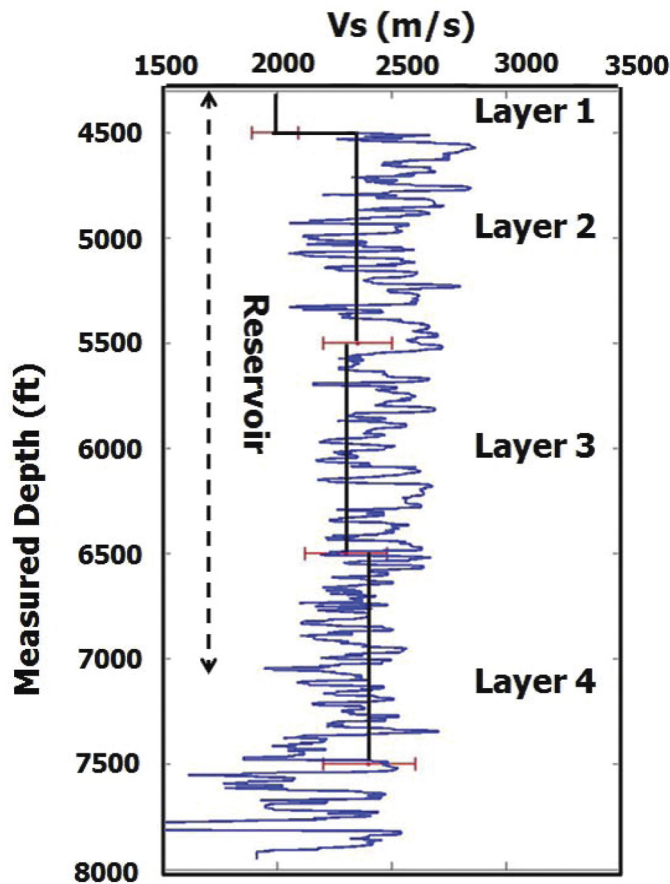


Figure 4. Overlay of vertical shear wave (S_v) velocity (black curves with error bars in red) from Dix-differentiated NMO ellipse and from dipole sonic log (in blue curve displayed after running window median filter with 25 ft window length). The reservoir interval is divided into four pseudo layers (Layer 1 to Layer 4) where interval NMO ellipses are computed.

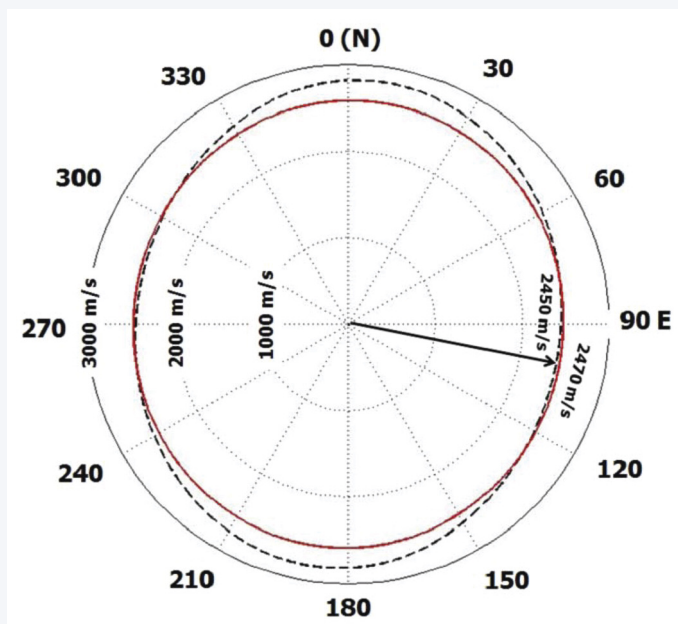


Figure 5. Interval NMO ellipses for S_v (red curve) and S_h (black dotted curve) modes in the pseudo layer-4 (shown in Figure 4).

The vertical interval velocity and the anisotropy parameter, A , corresponding to the two shear wave modes is estimated for the overburden and the reservoir interval in Williams Fork Formation. The estimation is based on equations 6 and 7. The vertical interval velocity profile within the reservoir interval for S_v mode is shown in Figure 4. The error bars (shown in red) are estimated by applying one way time picking error of 1 sample (2ms). The vertical velocity profile for S_h mode is not shown in Figure 4 because the average splitting coefficient over the reservoir interval is found to be small (1%). The interval NMO ellipse corresponding to pseudo-layer 4 (base of reservoir) is shown in Figure 5.

The values of $\sigma^{(v)}$, $\gamma^{(v)}$ and the semi-major axis of the interval NMO ellipse are also estimated for the overburden and the reservoir interval. The overburden has $\sigma^{(v)} = 0.17 \pm 0.06$ and $\gamma^{(v)} = 0.03 \pm 0.02$ and the reservoir interval has $\sigma^{(v)} = 0.11 \pm 0.07$ and $\gamma^{(v)} = 0.015 \pm 0.01$. Small values of $\sigma^{(v)}$ and $\gamma^{(v)}$ suggest that the rocks are unfractured in the reservoir interval of well 441-20. Grechka & Kachanov (2006) indicate that in dry circular cracks we expect approximate elliptical anisotropy ($\epsilon^{(v)} \sim \delta^{(v)}$) leading to $\sigma^{(v)} \sim 0$. This is the case in the RCP survey area where we do not have a water leg in the reservoir section of the Williams Fork Formation. However, the overburden above the Williams Fork Formation has water-filled cracks (Yurewicz et al. 2008). In this case we can expect a non-zero value of $\sigma^{(v)}$. The azimuth of the semi-major axis of the overburden is estimated at $165^\circ - 25^\circ$ and for the reservoir it is $100^\circ - 40^\circ$. The semi-major axis in the reservoir interval does not vary with depth and is consistent with the FMI interpretation of fractures in well 441-20 (Garrow, 2006). There is larger uncertainty of estimating the principal direction in the reservoir interval because of small fracture density at the location where the well 441-20 is drilled. The shear wave splitting from virtual source studies also suggests low fracture density within the reservoir interval. The evidence of low fracture density is also found in the FMI interpretation for fractures in well 441-20 (Garrow, 2006).

Velocity Macro-Model for VSP Migration

The vertical velocities for the fast and slow shear waves and the anisotropy parameters ($\sigma^{(v)}$ and $\gamma^{(v)}$) control the kinematics of these pure modes. It is thus important to take the anisotropy

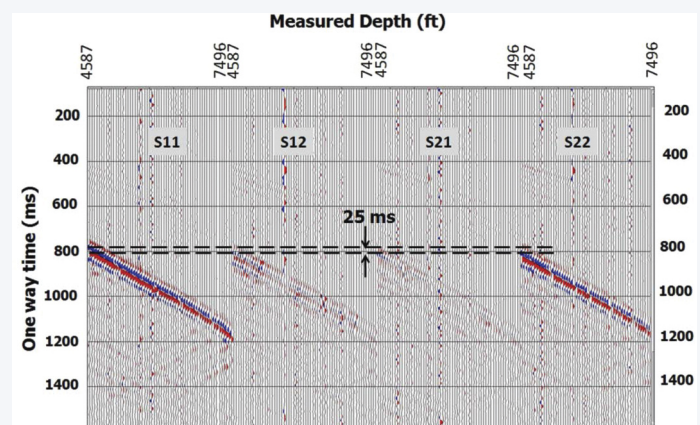


Figure 6. Shot record showing shear wave splitting ($\gamma^{(v)} = 3\%$) in the overburden. The shot location is about 250 ft from the well.

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Shear-wave sourced 3-D VSP Depth Imaging...

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parameters into account when building a migration velocity model for the $S^{\parallel}$ and $S^{\perp}$ waves. The simplest model that explains the splitting of shear waves at normal incidence is shown in Figure 6, and can be assumed to be HTI. Examination of a near-offset (250 ft) VSP shot record shows 25 ms splitting at the shallowest geophone (MD=4587 ft). This amounts to the splitting coefficient, $\gamma^{(V)} = 3\%$ in the overburden. The medium parameters for the overburden are estimated from the NMO ellipse as described above.

For the reservoir interval we find that the dipole sonic derived shear wave velocity and velocities from Dix-differentiation are same. Choice of either of these velocities can be used to populate the velocity model in the reservoir interval. The anisotropy coefficients $\sigma^{(V)} = 0$ and $\gamma^{(V)} = 0.015$ are assigned to the reservoir interval of the macro-velocity model. Although small, the anisotropy parameter of the reservoir, $\gamma^{(V)} = 0.015$, is crucial in optimal depth-positioning of the reflectors within the reservoir interval. The interval velocity in the coal layer is assigned a constant value of 1900 m/s (derived from well log) and anisotropy coefficients are set to zero. This could be an inappropriate assumption because coal has orthorhombic symmetry. The VSP survey did not have enough geophones to estimate the anisotropy parameters in the coal interval. The well does not penetrate to the Mancos Shale layer (below the Cameo Coal interval). So, it makes sense to populate the interval velocity using the surface seismic derived interval velocity. In Mancos Shale layer $\sigma^{(V)} = 0$ and $\gamma^{(V)} = 0$ is assumed and hence the velocity model in this layer is also approximate. A 2D line passing through the macro-velocity model is shown in Figure 7. This velocity model shall be used for migration of the VSP shot records.

Kirchhoff Prestack VSP Depth Migration

The primary objective of migration in the Rulison VSP survey area is to image the sandstones in the reservoir interval and in the Cameo Coal layers. The Kirchhoff depth migration method is used to migrate the shots in the RCP survey area. The Kirchhoff migration code had only the obliquity factor built into it and hence is not a true-amplitude migration. True-amplitude Kirchhoff migration additionally requires geometrical-spreading

factors. This spreading factor is necessary to calculate the weight term for migration. All the shots in the survey were divided into $60 \times 3^\circ$ azimuth sectors. The shots in the individual azimuthal bins were migrated using Kirchhoff migration scheme with migration aperture of 5500 ft. This aperture is considered adequate given the maximum source-receiver offset of 6500 ft. The output grid was in polar coordinates with size of $20 \text{ ft} \times 3^\circ \times 10 \text{ ft}$. The grid size is 20ft (in radial direction from the well 441-20), azimuthal increments of 3° and depth increments of 10ft. An output-grid dimension larger than $20 \text{ ft} \times 3^\circ \times 10 \text{ ft}$ resulted in spatial aliasing and significant degradation in the migration output. The azimuthal sectoring and migration was independently done for both $S^{\parallel}$ and $S^{\perp}$ -wave shot records. The image gathers were stacked resulting in 60 radial depth sections. The migrated stack output in polar coordinates was converted back to rectangular coordinates using bilinear interpolation. Conversion of polar stacks to rectangular coordinates resulted in $135 \text{ inline} \times 135 \text{ crossline}$ stacked sections each separated by 20 ft. Producing stack sections in a rectangular coordinate system enables loading the migrated data in commercially available

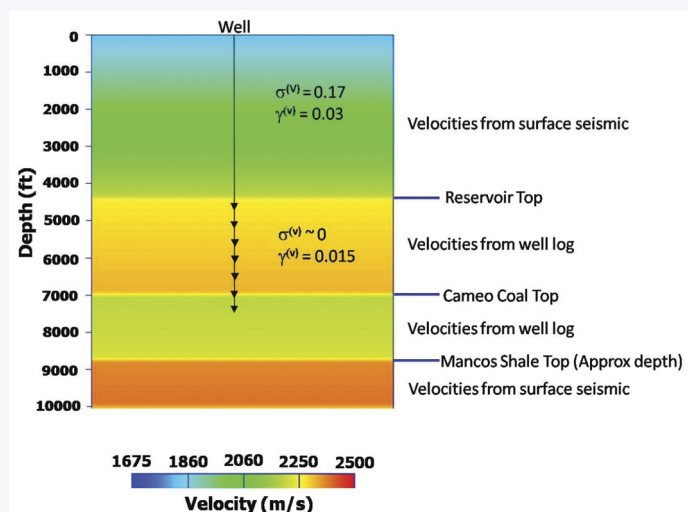


Figure 7. Shear wave velocity macro-model for migration.

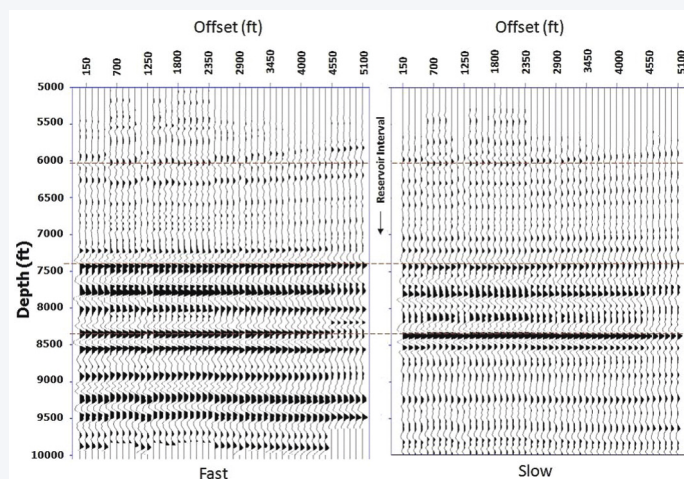


Figure 8. VSP common image gathers for the fast and slow shear wave reflections

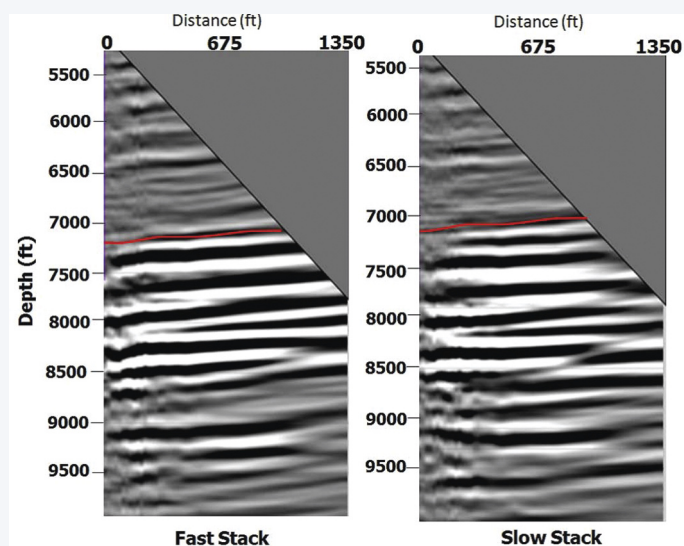


Figure 9. Fast and slow shear wave stacks of a line passing through the well 441-20. The well is at the left edge of both stacks. The marked horizon (in red) represents the top of the Cameo Coal layer.

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Shear-wave sourced 3-D VSP Depth Imaging...

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visualization systems (say, Landmark's SeisWorks, Jason Workbench etc.) for further interpretation. The common image gathers and reflection stacks for both fast and slow modes of shear waves are shown in Figure 8 and Figure 9 respectively.

The common image gathers (shown in Figure 4.13) are for both fast and slow shear waves. We observe some image distortions in the depths from 5000 ft to 6000 ft. The distortion, however, disappears at depths exceeding 6500 ft. The reason for the distortion is currently not well understood. It is possible that the distortions are related to inadequate aperture-effects for reflectors close to shallower geophones (4587 ft to 6000 ft) or it could be real and related to a fault. Further evaluation and geologic interpretation of the migrated data shall be made in a sequel paper.

Conclusions

Ray tracing in anisotropic velocity model is required for Kirchhoff depth migration of the shear wave reflections. In general, anisotropy parameters can be estimated by means of migration velocity analysis. However, a plausible velocity model can also be constructed using the interval velocities derived from surface seismic stacking velocities for shear waves, dipole sonic logs and the anisotropy parameters ($\sigma^{(V)}$ and $\gamma^{(V)}$). The values of ($\sigma^{(V)}$ and $\gamma^{(V)}$) in the overburden and reservoir interval are estimated using the traveltimes of transmitted shear waves. The overburden has larger values of ($\sigma^{(V)}$ and $\gamma^{(V)}$) than in the reservoir interval at the VSP well location. Reflection events in the common image gathers were found to be flat resulting in a prestack reflection dataset suitable for stacking. $\mathcal{R}$

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Prajnajyoti Mazumdar specializes in multicomponent 3-D VSP data acquisition, processing and interpretation with special interest in improving production from tight-sandstone reservoirs. He obtained his PhD in Geophysics from Colorado School of Mines in 2010 and M.Sc.Tech in Applied Geophysics from Indian School of Mines in 1998. He has over 10 years of experience in upstream oil and gas industry. During his studentship in Mines and associated industry internships he has worked on shear-wave virtual sources, permeability estimation from microseismic and engineering data, prestack full waveform inversion for estimation of rock properties and shear-wave VSP imaging projects.



Thomas L. Davis, Ph.D. is a Professor of Geophysics at Colorado School of Mines and Director of the Reservoir Characterization Project. He is active in the Society of Exploration Geophysicists as an organizer for technical conferences, workshops and continuing education programs and has served as SEG's Second Vice President, Technical Program Chairman, and Distinguished Lecturer. He received the C.J. Mackenzie Award from the Engineering College of the University of Saskatchewan, the Milton B. Dobrin Award from the University of Houston, and the Dean's Excellence and Melvin F. Coolbaugh Memorial Awards from the Colorado School of Mines. He was a co-recipient of the best poster award of the SEG in 2009 for a presentation on multicomponent seismic applications to tight gas fractured reservoir characterization.

Tight Gas Geophysics: AVO Inversion for Reservoir Characterization

David Close,* Simon Stirling, David Cho, and Frederik Horn

Schlumberger Canada; *Now at Apache Canada

Summary

A general discussion of some of the critical steps in AVO inversion workflows is included with a Western Canadian case study in this paper. We use the case study to illustrate that the ratio of the compressional and shear wave velocities (V_p/V_s) is a useful indicator of quartz-clay ratios in log data, and by extension suggest that V_p/V_s data from AVO inversion provide a means of characterizing, at least qualitatively, reservoir properties.

The case study utilizes petrophysical data processed in a consistent manner to produce mineral volume logs over the Doig and Montney Formations in addition to micro-seismic monitoring data from a horizontal well stimulation. These data are qualitatively correlated to the AVO inversion data. This case study, then, represents at least part of an integrated workflow for reservoir characterization in tight gas and shale gas plays.

Introduction

Integrated workflows for shale gas reservoirs have received increased attention following the step changes achieved in operational efficiency over the last decade. Du et al. (2009) presented such a workflow for the Barnett Shale play in Texas; however, a crucial link missing in their workflow was analysis and inversion of pre-stack seismic data. In Western Canada an increasing number of major leaseholders in the Horn River Basin and operators exploiting unconventional reservoirs in the Montney Formation are utilising pre-stack amplitude variation with offset (AVO) inversion data to assist in well placement and field development planning. However, such data is typically regarded differently by different members of an asset or development team. As reservoir characterization workflows for shale gas plays evolve, geophysicists must stress the place of 3D seismic data and advanced products (such as AVO inversion) in the workflow and illustrate means by which the data can be integrated in a manner that brings maximum uplift and assists in understanding lateral heterogeneity.

AVO inversion of 3D seismic data allows for the creation of V_p/V_s (or Poisson's ratio and/or λ - μ - ρ) volumes and maps of the reservoir interval, which reflect the heterogeneity of the reservoir associated with grain size and mineralogy. However, inversion data and other attributes derived from pre- or post-stack seismic data require corroboration from independent sources to confirm their utility. Data that can provide such calibration for these seismic based properties includes log based petrophysical data, micro-imaging data, production log data, production data, and micro-seismic monitoring data.

The heterogeneity of reservoir rocks within shale gas plays has been well established through wireline logging and

coreing and through empirical observations of stimulation and production response. Logging programs developed during the early part of this century to include spectroscopy based tools, which are capable of providing estimates of elemental proportions by weight and the relative abundance of naturally gamma-ray emitting elements (potassium – K, thorium – Th, and uranium – U). Determining elemental proportions allows the mineral contents to be determined and specifically the types of clay minerals present. Understanding the relative abundance of K-U-Th also assists in establishing total organic carbon (TOC) within the rock as kerogen can often be rich in Uranium. Shear sonic data and micro-image logs have also established their utility as they can identify changes in local stress associated with mineralogy, anisotropy in horizontal stress associated with tectonic forces, and natural fracture properties and abundance.

1. Petrophysical Data and Modelling

The area of Western Alberta where unconventional plays within the Montney and Lower Doig Formations are currently being exploited is mature in terms of exploration and production for conventional resources. Accordingly, there are a large number of wells that penetrate the Montney and Doig Formations that have been logged with standard triple-combo logging suites (i.e., resistivity-density-neutron logs). In the absence of spectroscopy data in older wells it is necessary to carefully construct petrophysical models capable of predicting mineral contents and TOC from standard log curves.

Key reservoir parameters, including total and effective porosity, mineral volumes (clay, quartz, carbonate), and volumes of kerogen and TOC can be estimated from standard log data where robust petrophysical models can be created. In the following case study a petrophysical model based on basin wide studies in the Western Canadian Sedimentary Basin (WCSB) is utilized. This model was constructed using classical statistical analysis techniques such as; histogram/frequency analyses, normality tests, cluster analysis and uncertainty analysis. Although such a model is no replacement for acquisition of high quality log data, in fields where there is little or no existing spectroscopy data and very little shear sonic and micro-image log data, empirical models that can accurately transform standard log data to advanced outputs are invaluable.

Where advanced logs and shear velocity data are available, the vertical heterogeneity through the potentially prospective zones can be measured. From these data it is observed that, in general, the ratio of compressional to shear sonic velocities (V_p/V_s) is a good indicator of sand-shale or quartz-clay ratios in shales and/or tight siltstones (Figure 1). Qualitatively and empirically, an increased sand-shale ratio correlates to increased porosity, lower breakdown pressures for stimulation, and enhanced relative production (Miller et al., 2007).

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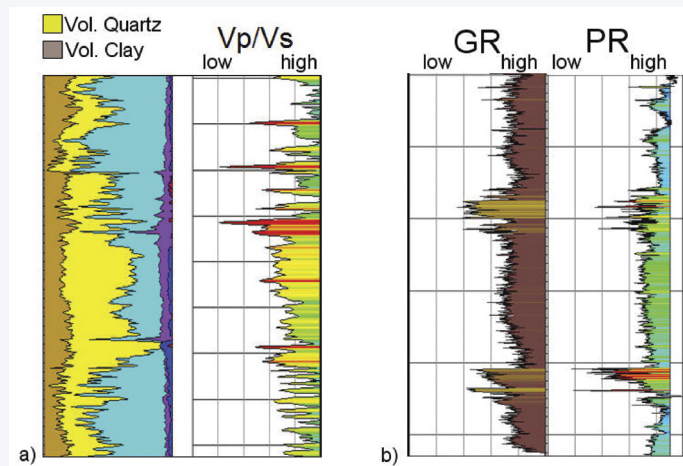


Figure 1. Log data that illustrate the correlation between low Vp/Vs ratio and/or Poisson's ratio (PR) with increased sand-shale content, from a) a Western Canadian shale gas play, and b) a South Texas tight gas play where low gamma ray (GR) is taken as a proxy for increased quartz content.

2. Amplitude Variation with Offset Inversion

AVO techniques exploit relative changes in seismic reflection amplitudes at varying incident angles to quantify changes in elastic properties at reflection boundaries, which can provide information regarding lithological and fluid properties of the formations. Through AVO inversion it is possible to derive an earth model that is consistent with measured seismic reflection data. This model can illuminate prospective subsurface areas characterized by anomalous physical properties (i.e., hydrocarbon reservoirs).

Seismic inversion techniques have been utilized since the 1970s (Pendrel, 2001). The implementation of inversion methods in the analysis of pre-stack seismic data (typically offset or angle stacks) provides the ability to derive quantitative estimates of the physical parameters that control the AVO response, namely the compressional and shear wave velocities and density, which can then be compared directly to measured well log data. Not only do the properties derived in the inversions have real physical meaning, they also benefit from the removal of wavelet effects and damping of noise outside the inversion operator range.

Standard AVO inversion workflows share a number of common steps; a brief discussion of some of the most critical (listed below) follows:

- 1) extracting wavelets,
- 2) low frequency modelling,
- 3) data inversion.

2.1. Extracting wavelets

The seismic wavelet represents the energy illuminating the subsurface and provides the connection between the subsurface elastic properties and seismic reflection data. This connection is represented through the convolutional model, which states that the seismic trace is the result of a convolution between a source wavelet and an earth reflectivity series. A typical wavelet extraction process uses the concept of the convolutional model where

a wavelet can be estimated by solving an inverse problem when the seismic trace and reflectivity series (calculated from well logs) are known. Because a convolution is a stationary process, this automatically assumes stationarity of the wavelet within the extraction window. Therefore, inversions that incorporate a wavelet are typically target oriented to justify the stationary wavelet assumption. To further compensate for the non-stationarity, separate wavelets are estimated independently for each angle stack using an angle dependent reflectivity series. This allows for a better representation of the offset dependent amplitude and phase variations observed in seismic data. It is also possible to implement time-varying wavelets, in amplitude and frequency, in some seismic inversion workflows. A time-varying wavelet can be important where assumptions regarding wavelet stationarity are not necessarily valid (e.g., where long estimation windows are required).

As the sonic and density logs are measured in depth and our seismic data in time, it is necessary to establish a time-depth relationship to relate the two domains. Where checkshot data are available, velocities are typically well constrained. In the absence of checkshot data, however, it is common to use prior knowledge about seismic horizons from regional surveys and geological formation tops (interpreted from well log data) as a guide along with sonic velocities measured during logging. Sonic velocities may be misleading as rarely are sonic data recorded to surface and as the well logs are measured at higher frequencies, relative to surface seismic data, the sonic velocities can be up to 10% higher than reflection seismic velocities.

To compensate for mis-ties between log-based synthetic seismograms and reflection data it is often necessary to make manual adjustments to the synthetic. However, there is much debate about the validity of this 'stretch-squeeze' approach. Indeed, with no a priori information about the source signature, it is typically not possible to determine definitively the amplitude and phase of the extracted wavelets and predict the correct velocity profile using stretch-squeeze corrections. When only one well is available for wavelet extraction, this non-uniqueness is an intractable problem. However, where multiple wells can be used to test wavelets, it is generally possible to predict a wavelet that produces synthetics with strong correlation to the reflection seismic data at multiple well locations.

A common pitfall of wavelet extraction is the over-reliance on statistical measures of fit between synthetic seismograms and measured data. If, as most algorithms do, a least squares approach is taken to wavelet extraction, the extracted wavelet will incorporate noise in a relentless attempt by the least squares algorithm to minimize misfit at this singular location. Therefore, wavelets with many side-lobes will generally improve measures of cross-correlation locally, but it is wrong headed to assume that this will provide a representative wavelet for the entire survey as this approach is simply incorporating local noise in the seismic data and errors in the log data measurements.

2.3. Low frequency modelling

Due to the band limited nature of seismic data, a low frequency (typically below ~10 Hz) model (LFM) is needed to represent the true elastic properties and must be included in the inversion solution from sources other than seismic reflection data. This

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information is typically obtained from well log data where a low pass filter is applied to isolate the low frequencies required for the inversion solution. Interpolation methods are generally utilized to populate the LFM by extrapolating calibrated logs using interpreted horizons and faults. The low frequency model may also be constrained by seismic velocities, depth trends and dip fields estimated from the seismic data or observed stratigraphic relationships.

The most critical decision in constructing the LFM is the number of wells selected to influence or contribute. As the questions of where and how properties change relative to the well control points are unknown, constructing an LFM is inherently interpretive and non-unique. Therefore, proper care must be exercised in the interpretation of the low frequency trends in the final inversion property volumes.

2.4. Seismic Data inversion

The basis of all AVO studies is the plane wave Zoeppritz equations, which are parameterized in terms of P-wave velocity (V_p), S-wave velocity (V_s) and density. However, due to its complex nature, approximations were sought to obtain a more practical representation of the angle dependent reflectivity. Aki and Richards (1980) provide an approximation in terms of changes in V_p , V_s and density by making the following three assumptions: 1) The relative changes in properties are small, 2) second order terms can be neglected, and 3) the incident angle does not approach critical. Subsequently, further approximations of the Aki-Richards equation that are often implemented were provided by Shuey (1985), Smith and Gidlow (1987), Hiltermann (1989), and Fatti et al. (1994), all of which implement various assumptions and reparameterizations of the three fundamental properties. Therefore, many forms of the AVO equation exist and can be used as the underlying physics of the inversion depending on the objectives of the study.

Inversion methods can be categorized into two types, direct methods and iterative methods. The direct method is typically used for small scale inverse problems (i.e., wavelet estimation) where an inverse to the forward operator can be achieved with sufficient efficiency. Large scale inverse problems (i.e., 3D simultaneous AVO inversions) on the other hand, are much more demanding computationally and thus require a more effective approach such as an iterative method. In general, iterative methods make use of forward modelling where a synthetic dataset is generated from a model (the solution sought) that is updated iteratively. The differences between synthetic and observed data then become part of the objective function that must be minimized to achieve the optimal solution.

The ISIS* inversion software, which is utilized in the following case study, uses a simulated annealing optimization algorithm. This approach is analogous to a cooling system, where given sufficient time the system achieves its lowest energy state, or in the case of inversion locate the global minima in the objective function. One major advantage of this approach is that it has the ability to escape local minima and is thus considered a global optimization algorithm.

*Mark of Schlumberger

3. Amplitude and Velocity Variation with Azimuth

Standard seismic processing and inversion workflows treat data from all azimuths equally during stacking, however, that the subsurface is often anisotropic in terms of seismic and sonic velocities is well established. Media such as shales, where minerals are prone to alignment, typically exhibit vertical transverse isotropy (VTI). Media strongly affected by fractures or tectonic stress typically exhibit horizontal transverse isotropy (HTI). In HTI media the travel time paths will differ azimuthally over an equal distance, this gives rise to a fast and slow direction of travel. Where aligned fractures are the source of the HTI the fast direction is aligned with the dominant fracture orientation, and where stress anisotropy is the source of the HTI it is the direction of maximum horizontal stress that defines the fast direction.

By stacking seismic data on the basis of azimuth it is possible to extract information regarding the relative magnitude of HTI anisotropy in the subsurface. By examining plots of traces sorted by common offset and common azimuth (COCA), event misalignment associated with HTI anisotropy may be evident (Figure 2).

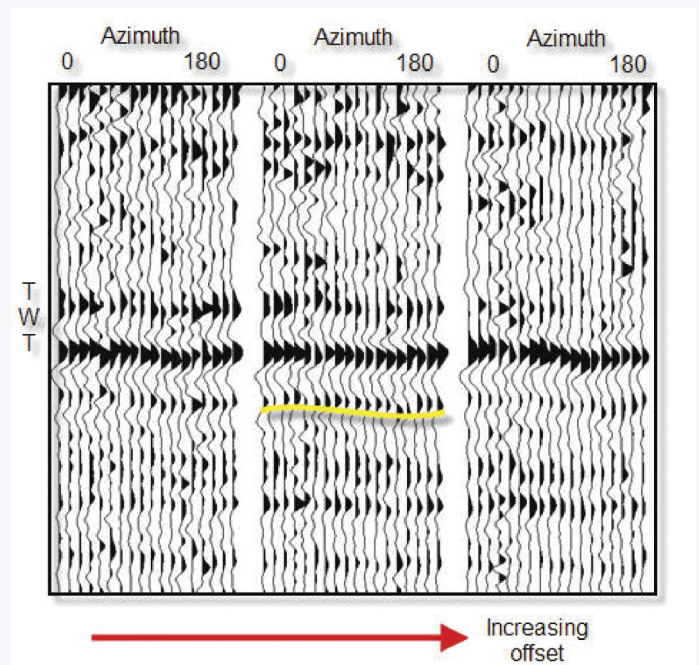


Figure 2. Common offset – common azimuth (COCA) plot illustrating traces from specific offset ranges arranged or sorted by azimuth. In HTI media a horizontal reflector will manifest as a sinusoidal reflection in a COCA plot.

A common analogy used to illustrate the effects of HTI is based on Oreo cookies, where the delicious gooey cream filling represents fluids and/or rock gouge in fractures and the sweet dark biscuit represents the coherent rock between fractures. When Oreo cookies are stacked horizontally (Figure 3a) the seismic travel times through the stack in any direction are equal. If the cookies are aligned on their edges, however, the travel time paths form an ellipse where the shortest travel time is for paths that are aligned with the fractures as the energy can transfer entirely through coherent rock and avoid passing through the gas/fluid/rock gouge (Figure 3b).

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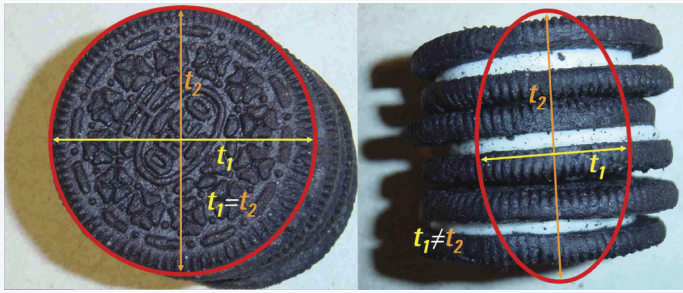


Figure 3. The Oreo analogy for HTI anisotropy. a) No HTI anisotropy results in equal travel time paths in all azimuths, and b) In an HTI anisotropic media with aligned vertical fractures the travel time is azimuth dependent and is not equal in all directions.

The analysis of velocity variation with azimuth (VVAZ) and amplitude variation with azimuth (AVAZ) can provide important information regarding either fracture density and/or stress anisotropy. Both natural fractures and stress anisotropy are of critical importance to planning of hydraulic fracture stimulation, where much of the finding and development costs in shale gas plays are concentrated. Generally well log data is required to identify the source of the HTI as either aligned fractures, stress anisotropy or some combination thereof.

4. Reservoir Modelling and Geophysics: A Case Study from North-West Alberta

4.1. Geological Setting

The Triassic Montney Formation of the WCSB is a marine clastic rock deposited in a continental margin basin. The Formation comprises fine-grained (silt to shale) rocks with morphologically controlled interbedded sandstones. Carbonate content varies and can be locally abundant in similar proportions to quartz content. The Upper Montney comprises stacked sections of distal

shoreface to shelf siltstones up to 150 m thick with laminae of pyrite bearing organic material (Hayes, 2009).

Due to the low (sub-millidarcy) permeability, horizontal completions and hydraulic fracturing are required to generate economic production levels. The economics of individual wells are generally improved by increasing the length of the lateral section and stimulating with multiple, separate hydraulic fracture stages. The very high costs of the stimulation are such that there is, justifiably, a strong focus on engineering in the development of the Montney Formation and other tight gas reservoirs. In this paper we present the case for utilizing geophysics, in conjunction with all other data, to understand lateral heterogeneity and optimize field development within the Upper Montney and Lower Doig Formations in an area of north-west Alberta between Grand Prairie (AB) and Dawson (B.C.).

4.2. Petrophysical Data

A total of 8 wells with density and sonic logs that penetrate the Lower Doig and Upper Montney formations were utilized in this study. Each of the wells was processed in a consistent manner (using the model described previously). The zone of interest in this area averages around 40 to 50 metres in thickness. Analysis of these wells through the zone of interest (Figure 4) illustrates the varying rock quality and thickness. The porosity-height values for the combined interval from the Lower Doig to the Base Upper Montney and for the Upper Montney only are included in Figure 4.

4.3. Seismic Inversion

Using the ISIS simultaneous inversion algorithm four angle stacks (0-12°, 12-18°, 18-25°, and 25-30°) were inverted for acoustic impedance, Vp/Vs ratio, and density. The angle ranges for the four angle stacks were selected to optimize the fold, and hence signal-to-noise ratio, in each angle stack over the zone of

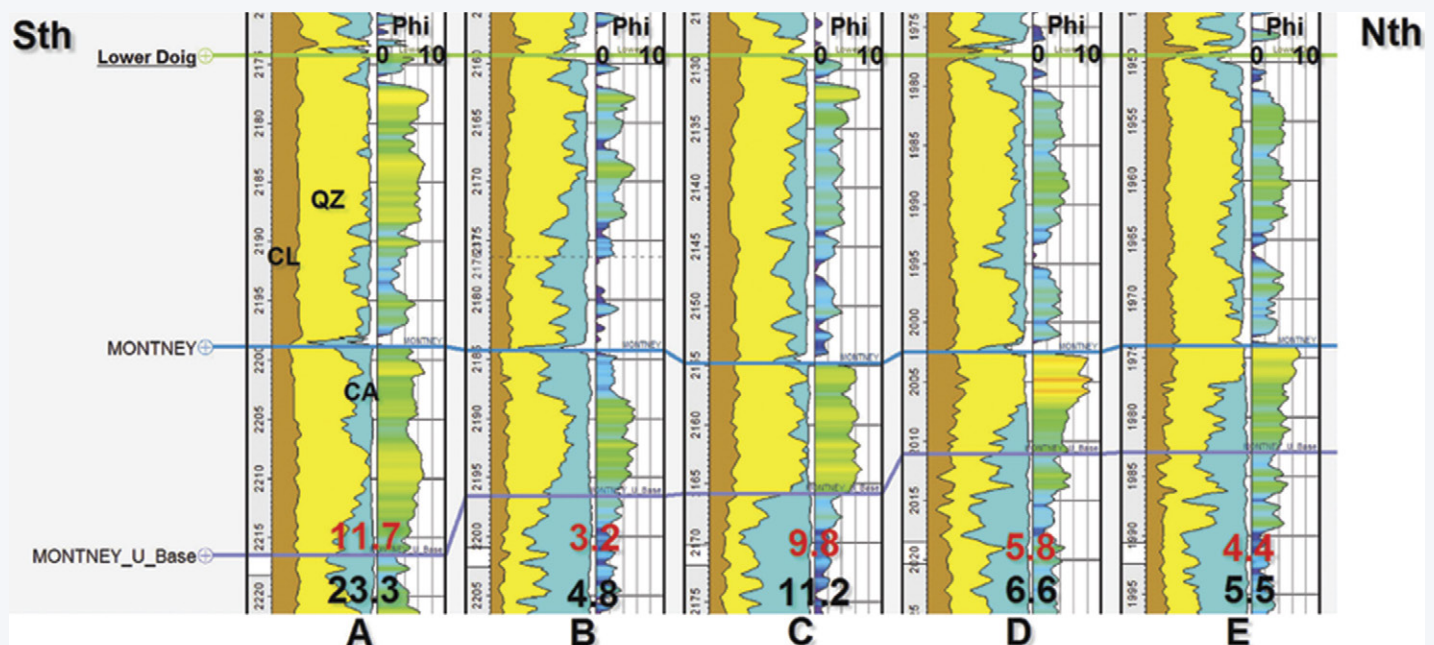


Figure 4. A north-south section through five wells over the zone of interest. Bold numbers at the bottom of each well panel indicate porosity-height: red values for the Upper Montney only and black for the combined Lower Doig and Upper Montney. QZ=Quartz, CL=Clay, CA=Carbonate.

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interest. The extracted wavelet for the near angle stack and its associated synthetic is illustrated in Figure 5.

Results of the inversion for acoustic impedance and V_p/V_s ratio are illustrated in Figure 6, where they are compared to well log data from that location. These results exhibit a good correlation to well log data and confirm that the inversion is capable of predicting these properties. To test the hypotheses that the V_p/V_s ratio is a good indicator of reservoir quality, horizon or

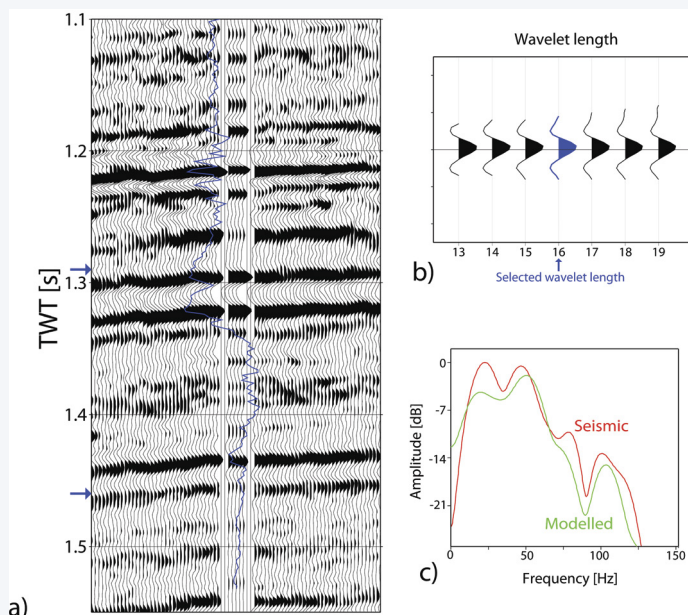


Figure 5. a) Synthetic seismogram based on the angle impedance well log (blue curve) inserted into seismic data from near angle stack, b) a Suite of wavelets extracted over the zone of interest (defined by blue arrows in (a)) with varying length, the wavelet selected for inversion is highlighted in blue, and c) the amplitude spectra for the synthetic seismogram and seismic data over the zone of interest highlighted in (a).

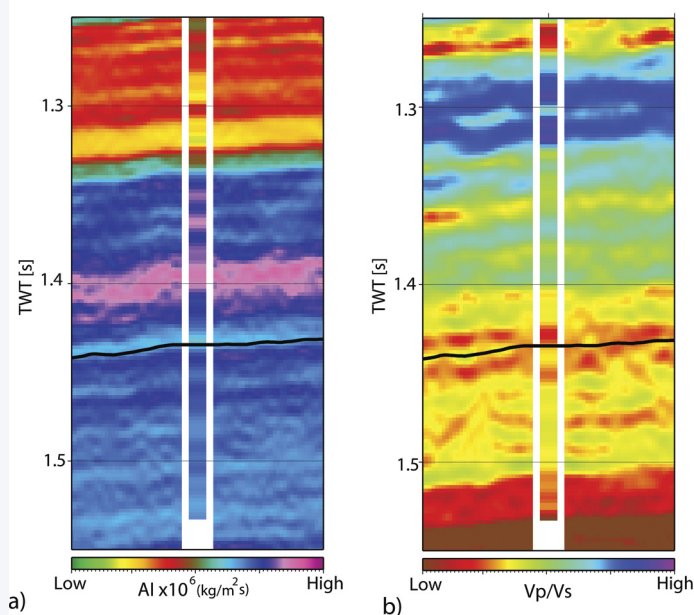


Figure 6. a) Acoustic impedance (AI) and, b) V_p/V_s ratio logs inserted into their respective inversion volumes. The zone of interest is illustrated by the bold dark horizon at ~1.425 s TWT.

stratal slices through the V_p/V_s ratio volume are compared to porosity-height maps (Figure 7).

In general the V_p/V_s and/or Poisson's ratio maps are a good indicator of porosity development within the Lower Doig/Upper Montney in the wells used in this study. However, in the absence of a larger dataset of wells this inference can not be backed up in a statistically meaningful manner. The AVO attribute map included in Figure 7 is only one of several possible and reasonable interval maps that could be created as hydraulic fracture stimulations grow in height to encompass tens of metres, and sometimes much more. Accordingly it is not unreasonable to include in our stratal slices a greater interval than that immediately surrounding our target horizon.

In addition to correlating inversion data to petrophysical estimates of porosity-height in this case study, micro-seismic monitoring results are also correlated with maps of inversion properties. Micro-seismic data are available in the study area from a horizontal well with an ~1100 metre lateral section in the north of the study area (Figure 7). The well was stimulated in five stages using a multi-stage open-hole completion, isolated with packers and ball-actuated ports. The treatments were monitored in a vertical well close to the centre and slightly to the north of the lateral section. The micro-seismic data recorded for stages 1 and 2 varies markedly from that recorded for stages 4 and 5 (Figure 8). No data were recorded for stage 3 as no fracture could be initiated, which is assumed to be a result of either a failure with the completion mechanism (although there was no conclusive evidence of this), or of changes in reservoir properties that increased the break-down pressure of the formation beyond that of the tubular limit imposed.

Figure 8 illustrates that relatively few micro-seismic events are recorded from stages 1 and 2 relative to stages 4 and 5, and additionally the distribution of the points is also markedly different. The concentration of micro-seismic events measured during pumping stages 1 and 2 to the north of the lateral suggest an asymmetric fracture propagation that created a complex, potentially less effectively-connected swarm of induced fractures from which to produce. The events from stage 2 also concentrate in the same area as stage 1, which indicates that new reservoir is not being stimulated during stage 2. In contrast, a greater number of events, which on average have a larger amplitude, were measured during stages 4 and 5. The alignment of events from stages 4 and 5 is also much closer to the expected orientation based on knowledge of regional stresses.

The stimulation stages were designed to be approximately equivalent in terms of total fluids and proppant pumped, the assumption being that induced fracture networks should be very similar for each stage. Although it is certainly possible that stimulation design and implementation practice, and not reservoir related properties, could explain the observations regarding the micro-seismic event patterns discussed above, we consider that changes in formation properties underpin the variable micro-seismic response. The increased V_p/V_s ratio indicated by the AVO results around the stage 3 frac port suggests that a higher breakdown pressure would be expected due to increased clay mineral content, and this may explain the failure to initiate a fracture for this stage. Stages 4 and 5 are located in a more extensive area of lower V_p/V_s ratio (Figure 8), typically representative

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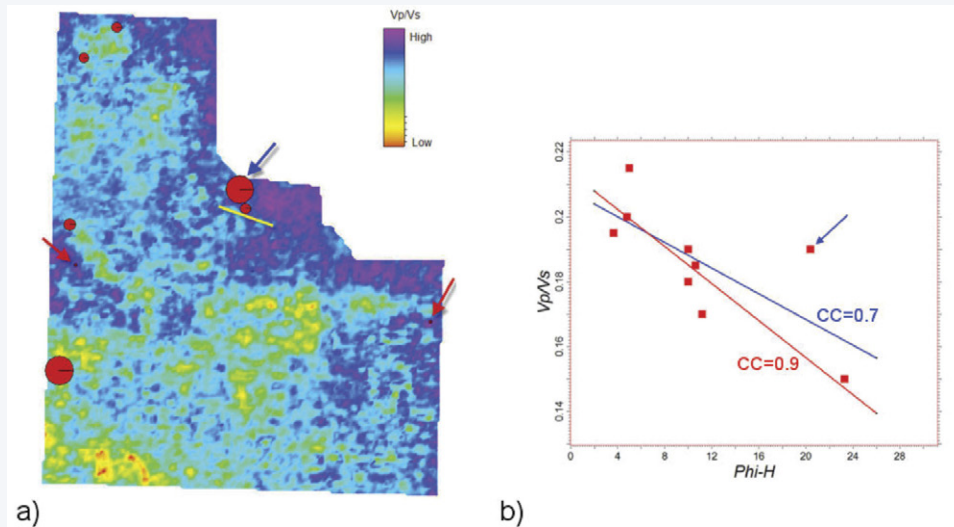


Figure 7. a) Map of median Vp/Vs ratio value and porosity-height from 8 wells through the Lower Doig and Upper Montney. The red arrows highlight wells with very small porosity-height values and correspond in general to areas of higher Vp/Vs ratio. The blue arrow highlights a well at the edge of the seismic data where the inversion is adversely affected by decreased fold. The yellow line is the approximate location of a horizontal well where micro-seismic data were recorded during stimulation. b) Cross-plot of porosity-height values as shown in (a) against Vp/Vs extracted from the map. The correlation co-efficient of all data points (blue line) of 0.7 is improved to 0.9 (red line) by removing the data point marked by the blue arrow which again corresponds to the well near the edge of the survey (a).

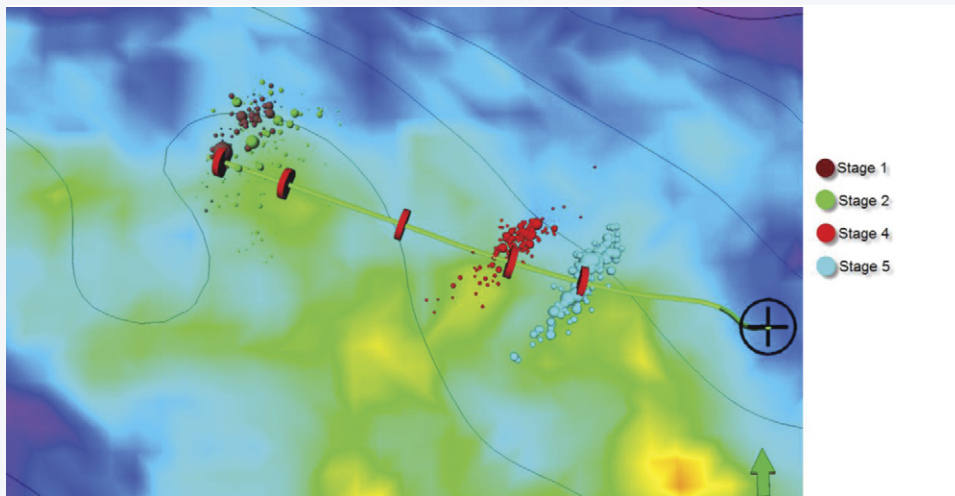


Figure 8. Micro-seismic monitoring data overlain with a Vp/Vs ratio map from AVO inversion. Fracture stimulation ports (frac ports) are located as red disks along the lateral.

of higher relative quartz content, which explains, at least in part, the improved stimulation results.

A possible alternative and/or complementary interpretation of the micro-seismic data pattern can be found in the amplitude versus azimuth (AVAZ) data. These data provide an indication of the degree of azimuthal anisotropy of seismic amplitudes. The anisotropy indicated by the AVAZ is substantially higher (by a factor of ~2) towards the heel of the well (i.e., stages 4 and 5) relative to the toe of the well (i.e., stages 1 and 2) (Figure 9). However, as the well is located near (<500 m) the northern limit of the survey the azimuthal distribution of data is imperfect and the consequence of this on the results is difficult to quantify. Regardless, we can say that for this example there is a strong empirical relationship between induced fracture complexity and AVAZ anisotropy.

4.4. Stimulation

Hydraulic fracture stimulation is critical to the economic production of tight gas and shale gas plays. Increasing the exposed surface area and volume of rock around the wellbore that is stimulated, and therefore capable of contributing to production, drives down the lifting costs of development. This makes stimulation efficacy a key focus of development. Horizontal drilling is a key and obvious means of contacting greater amounts of reservoir, and has been the single most critical step in the economic exploitation of tight gas and shale gas plays. In addition to horizontal drilling, advances in completion and stimulation technology have provided means of contacting greater volumes of reservoir. Optimal stimulation strategies can be formulated according to geological and geomechanical conditions. The choices of fluid type, additives, proppant size and concentration, pumping rates, monitoring and diversion technology are generally dictated by material and operational costs and how any modeled or perceived increase in production offset these costs over the economic life of the well.

The stimulation detailed in this case study utilized gelled "frac-oil", a refined gas-condensate, which is perceived by some reservoir engineers to result in less damage to the formation as laboratory tests on core suggest the recovered permeability is greater for oil-based fluids. However, theory, and field results, indicates that the differential is short-lived and although the flow back of stimulation fluids may occur slightly more rapidly, the overall producibility of the reservoir is not improved by more expensive oil-based fluids relative to appropriately designed water-based

fluids. Effective production is ultimately dictated by the conductivity contrast provided by the fracture, relative to the formation capacity to produce from the exposed surface area. The stimulation plan for this well called for each stage to pump ~50 tonnes of proppant; however, stages 4 and 5 ultimately received greater volumes, due to the available excess from failure to place proppant into the formation during stage 3.

The average volumes of proppant pumped in this area is currently between 80 and 100 tonnes per stage with associated bulk fluid volumes of ~200 m³. The current trend for wells exploiting the Montney Formation in western Alberta is to stimulate with foamed fluids, due to their capacity to hold proppant in suspension, efficiency in creating fracture volume (low leak-off rate), and relatively high retained fracture conductivity. Additionally, the bulk volume of fluid injected is either nitrogen

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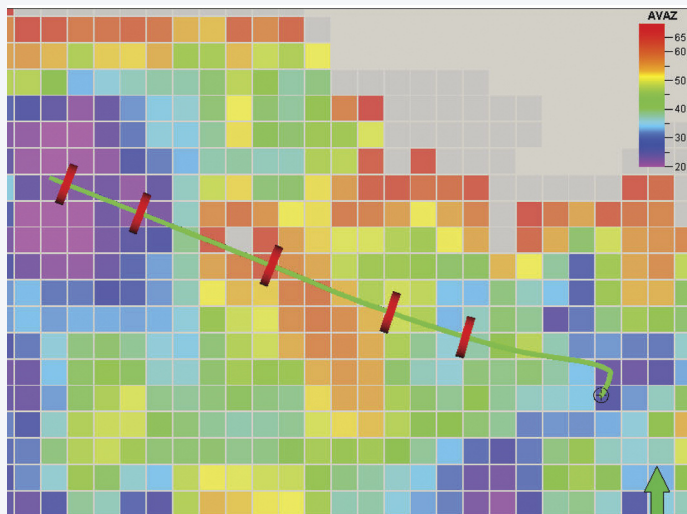


Figure 9. The amplitude versus azimuth (AVAZ) data, derived from 3D seismic data, indicate non-uniform stress distribution along the length of the lateral that is characterized by lower anisotropy towards the toe of the well in the region of fracture stimulation stages 1 and 2.

(N₂) or carbon dioxide (CO₂), effectively limiting the volume of residual water to flow back. The increased viscosity of foam-fluids relative to fluids such as friction-reduced water, or “slick-water”, results in better proppant transport and distribution within the fracture; whereas with slick-water as soon as fluid velocities are not sufficient to maintain turbulent flow that supports the proppant it drops to the base of the fracture. Fluid leak-off into the matrix adjacent the fracture-face is not considered an issue in shale gas plays, where permeabilities are in the nano-darcy range. Fluid leak-off can be an issue, however, in the Montney formation of western Alberta, as it is slightly coarser grained and in general has higher permeabilities (on the order of micro-darcies) relative to the more distal Montney Formation in eastern British Columbia.

Foam fluids are typically energized by N₂ or CO₂, and have surfactants added to increase viscosity. The gas fraction generally makes up approximately three-quarters of the total fluid volume and assists in increasing the viscosity (shaving foam makes an appropriate analogy). Due to the greater density of CO₂ relative to N₂, an equivalent volume of CO₂ foam delivers greater hydrostatic pressure, but the greater cost of CO₂ pumping may offset this advantage if the additional hydrostatic pressure is not required. Due to the greater viscosity of foam fluids relative to slickwater (Figure 10) an added advantage is that lower pump rates are required (~2 m³/min) relative to slick-water jobs (~8-20 m³/min). Foam fluid jobs therefore typically require less horsepower and machinery at surface, which partially offsets the greater cost of materials relative to slick-water treatments.

Where grain size decreases (and, therefore, typically permeability), and overall clay content increases in the Montney Formation in British Columbia stimulation strategies are generally more closely aligned with other North American shale-gas plays such as the Horn River Basin. In these plays, where nano-darcy permeabilities prevail, slick-water stimulations are the norm. This is partly driven by economics as slick-water is the



Figure 10. Several seconds after ceasing vigorous agitation the proppant is no longer suspended in slick-water (left jar) whereas the proppant remains in suspension in the gel-like consistency of the foam fluid (Schlumberger ClearFRAC base-fluid in this example; right jar).

lowest-cost stimulation fluid and the shale-gas plays require larger volumes of proppant so the discount of slick-water over gas is meaningful, but it is also partly a function of the formation response to stimulation. As the permeability of the rock in these plays is so low, there are very low leak-off rates, which leads to higher efficiency of fracture generation and the tendency to create complex high-surface-area fracture networks (at least in theory, real time micro-seismic monitoring or post stimulation logging are required to confirm such assumptions). The greater pump rates referred to above are required to maintain fluid velocity, and therefore proppant suspension as far as possible into the fracture network. Additionally, fine-mesh proppants are often substituted, sacrificing fracture conductivity to aid transport.

With the high costs of hydraulic stimulation raw materials (~\$300/T for 20-40 sand proppant) and fluids, people and machinery (>\$1M for a typical 6-8 stage stimulation) the drive towards lean and efficient stimulation is inevitable, and will include increasing the length of laterals and the number of stages stimulated. This is primarily an engineering issue, however, if and where geology and geophysics can provide increases in efficiencies through improved understanding of the reservoir, the cost of this work will likely be paid out many times over.

5. Conclusions

Geophysics and specifically AVO inversion can bring significant uplift to tight gas and shale gas reservoir characterization studies. Variations in V_p/V_s ratio can be used to investigate and understand heterogeneity in reservoirs related to facies variations and changes in grain size and mineralogy. The AVO results presented here are correlated to both petrophysical modelling results from a number of wells and micro-seismic monitoring data from a single well. The continuation of this workflow is to integrate production data and decline curve analysis with volumetrics predicted from reservoir models based on log data at well locations and AVO inversion data between the wells.

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Geophysical data, beyond simple horizon and fault picks, are needed to provide uplift and meaningful input in tight gas and shale gas plays. The potential benefits, in terms of mapping and well location high-grading, must be illustrated to asset teams reluctant to utilize geophysics. However, just as important as this is managing expectations associated with geophysical data and its interpretation by pointing out the limitations alongside the benefits and uplift. This case study delivers a single example of this, which provides a framework for the means in which geophysics can, and we believe, should be utilized in an integrated workflow. *R*

Acknowledgements

We would like to acknowledge the helpful and insightful comments and reviews by Richard Marcinew (Schlumberger Well Services) and the technical assistance of Maggie Malapad and Sean Johnston (Schlumberger Canada), and Greg Cameron (WesternGeco Canada). Richard Parker and Mike Jones (Schlumberger Canada) provided the micro-seismic data, via a cooperative anonymous client who we also thank. Patty Evans provided the seismic data from the WesternGeco Multiclient library and David Paddock (WesternGeco Houston) provided the basis of the Oreo cookie analogy.

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David Close received a B.Sc. (Hons.) in Geology from the University of Tasmania, Australia, where he specialized in minerals exploration and electrical geophysics. David went on to complete a D.Phil. in Marine Geology and Geophysics at the University of Oxford, UK, where he studied as a Rhodes Scholar and undertook research on passive rift margin evolution and basin development.

David previously worked with Schlumberger in Mexico, U.S.A., and Canada as a wireline engineer, borehole geologist, reservoir geomodeller, and AVO inversion geophysicist and currently works with Apache Canada in Calgary. David is a member of the SEG, CSEG, AAPG and AGU.



Simon Stirling graduated from the University of Saskatchewan in 1998 with an advanced degree from the Department of Physics and Engineering Physics majoring in Physics and Mathematics. He joined Schlumberger in 1999 as a wireline engineer before assuming a position with Schlumberger Data Services in 2005 as a log analyst. He is currently a Senior Petrophysicist with Consulting

Services department of Schlumberger in Calgary with worldwide experience in clastic and carbonate environments in both conventional and unconventional reservoirs. He is a member of SPE, CWLS and SPWLA.



David Cho graduated from the University of Calgary in 2007 with a B.Sc. in Physics and a B.Sc. in Geophysics. During his undergraduate studies, he worked for the Institute for Space Research and the CREWES project at the University of Calgary. He joined Schlumberger in 2008 as a Geophysicist in the Reservoir Seismic Services group where he specializes in AVO, inversion and reservoir characterization studies. He is currently enrolled in the M.Sc. program in Geophysics at the University of Calgary. He is a member of the SEG, CSEG, AGU and APEGGA.



Frederik Horn received his B.Sc. degree in Physics and Mathematics and his M.Sc. in Geophysics from University of Copenhagen, Denmark. After a few years in environmental geophysics he joined Danish AVO inversion company Odegaard and remained through the acquisition by WesternGeco and again through the acquisition by Schlumberger. From 2007 to 2010 he was; Canada Manger for Schlumberger Reservoir Seismic Services. He is currently Senior Inversion Specialist with WesternGeco in Denmark. His expertise includes; pre-stack seismic inversion, AVO, wavelet theory and geophysical modelling. Frederik is a member of the SEG, CSEG and EAGE.

March 25, 2010

CSEG Annual General Meeting

Photos by Penny Colton.



2010 Council (Incoming and Outgoing Executive and Editors): L-R: Back Row: S. Chopra, F.Aubin, K.Manchul, B.Hassell, K.Jamison, C.Laws, M.Perz, L.Herd, C.Mangat. Front Row: J.Leslie-Panek, T.Haglund, J.Downton, J.Townsley, J.Fernando, D.Nordin. (Not in photo: B.Jose, P.Barnollar, C.Hooge).



CSEG Meritorious Service for John Logel; his acceptance (from Norway) is played as a video for the large audience (on screen on left).



CSEG 2010 Executives and Staff: (L-R): Back Row: Jim Racette, Dave Nordin, John Fernando, Mike Perz, Kelly Jamison, Cheran Mangat, Larry Herd. Front Row: Kristy Manchul, Jon Downton, John Townsley, Sheryl Meggeson. (Not in photo: Barry Jose, Pratt Barnollar).



CSEG MEDAL is presented to Warner Loven. (L-R): Bud St Clair (CAGC), Warner Loven, Joy Loven, Francois Aubin (CSEG Past President).

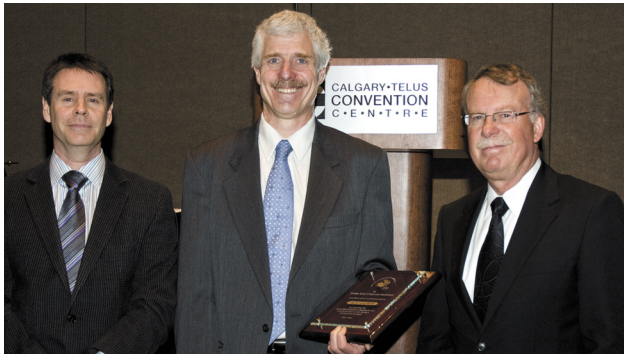


Tooney Fink accepts Meritorious Service Award.

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CSEG Annual General Meeting

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AGM Luncheon Speaker and CSEG 2009 Distinguished Lecturer, Richard S. Smith (center) of Laurentian University, was introduced by Doug McConnell (L), and thanked by Brian Russell (R).



Brock Hassell presents the CSEG 2009 Financial Report.



Peter Duncan accepts CSEG Honorary Membership. (L-R: Francois Aubin, Peter Duncan, Brian Russell.



Tooney Fink (right) accepts CSEG Meritorious Service Award from Stan Lavender (left).



John Townsley (L) receives the 2010 CSEG gavel from Jon Downton (R).

CSEG Scholarships

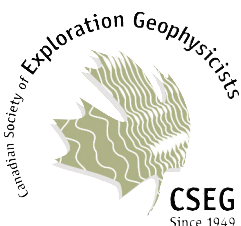
Dennis Melrose (Nexen Inc.), Hassan Odhwani (Divestco), Matthew Klukas (Talisman)

The CSEG Scholarship Committee is a part of the CSEG Foundation and is run by a minimum of 3 volunteers in any given year. The scholarships are funded primarily through generous corporate and individual donations, and through interest generated by memorial trust funds.

Every year the CSEG Scholarship Committee distributes scholarships to deserving candidates at Universities across Canada. The criteria for receiving a scholarship include enrollment in a program leading to a career or research in exploration geophysics, academic performance, financial need and involvement in extra-curricular activities. Twenty three companies, trust funds and individuals donated a total of \$40,000 in 2009 totaling 20 scholarships. The CSEG presented 23 scholarships in 2008 and 21 in 2007. Our goal is to grow the number of scholarships we distribute each year by increasing the number of industry sponsors. All scholarships have a value of \$2,000. Many companies fully sponsor a scholarship with a donation of \$2,000 while others partially sponsor scholarships with donations of \$500 or \$1000.

The 2010 Scholarship Committee (Dennis Melrose, Hassan Odhwani and Matthew Klukas) is currently soliciting donations for the 2010/2011 academic year. Donation request letters were sent out in March to companies and individuals and are currently following up with a phone campaign. If you are interested in contributing and have not yet been personally contacted by the CSEG Scholarship Committee, we are gratefully accepting donations. Please contact a member of the committee or mail funds to the CSEG office with cheques payable to the CSEG Foundation. We ask that you clearly indicate that the funds are for a CSEG scholarship. All donations are tax deductible and a charitable donation receipt will be issued.

The CSEG scholarship committee would like to thank all of the generous scholarship sponsors for their support in 2009. Your support contributes to the advancement of the field of geophysics, and the education of students pursuing a career in exploration geophysics.



2009 CSEG Scholarship Sponsors

Dr. Larry R. Lines

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CSEG Scholarships

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Aaron DesRoches, Ph.D at the University of New Brunswick sponsored by Dr. Larry Lines and the CSEG Foundation. Aaron completed his B.Sc. in Geology at the University of New Brunswick in 2004, where he took an interest in environmental geosciences and applied geophysics. In April 2008 he completed his M.Sc thesis at Simon Fraser University, focused on analyzing

and interpreting numerous borehole geophysical logs and sedimentary core (~1000m) from the subsurface of Alberta. The collected data was compiled into various modelling packages and were used to generate a series of cross-sectional profiles and a depositional model for the subsurface. His research in this field was awarded "Best Graduate Thesis – M.Sc 2009" by the Canadian Society of Petroleum Geology. Following graduation, Mr. DesRoches was employed as a technical specialist in the geoscience division at the Nuclear Waste Management Organization (NWMO) in Toronto. At NWMO he was involved in the management of large-scale geosciences initiatives related to the development of a centralized deep geological repository for the safe storage of used nuclear fuel in Canada. Mr. DesRoches' current PhD work at the University of New Brunswick is research to develop a geophysical-approach used to identify characteristics of groundwater flow paths within overburden and fractured bedrock aquifer systems.



Abdolnaser Yousefzadeh, Ph.D at the University of Calgary sponsored by Enerplus. Abdolnaser Yousefzadeh obtained his B.Sc. in geology from Shahid-Bahonar University of Kerman, in 1997 and his M.Sc. in geophysics from Institute of Geophysics, University of Tehran, Iran, in 2001. He worked for four years in the oil industry in Iran before moving to

Canada in 2005. Naser started his Ph.D. program with CREWES in September 2008, after transferring from University of Alberta. His research interests seismic data processing and imaging problems. His current research focus is on using the multigrid method for solving a system of linear equation of the least squares Kirchhoff prestack migration, under the supervision of Dr. John C. Bancroft.



Akshay Gulati, M.Sc. at the University of Calgary sponsored by Hampson-Russell Software Services. I always had a keen interest in "How things work". This pushed my interest in Physics and Mathematics with its application to real world problems impugned me to pursue engineering in my graduate degree. Physics and Engineering is surrounded with highly

challenging complex problems, which can be solved using computing. After a year I went into research in Earth Science at IIT Mumbai (Indian Institute of Technology) to apply whatever I had learned in last 5 years. During my tenure as a research assistant I published papers as well as few chapters in a book related to Engineering geology and soft computing. After a year, I got an opportunity to do Master of Science from the University of Calgary, sponsored by CREWES (Consortium for Research in Elastic Wave Exploration Seismology). My thesis work deals with the algorithms designed to reconstruct improperly sampled wave fields.

I love coding, in my spare time I develop games for my iPhone. In terms of career aspirations, I strive for an outstanding career working with outstanding people at a major oil and gas company.



Brad Ohler, 3rd year of B.Sc. at the University of Alberta sponsored by Pengrowth Energy Trust, Seisland Surveys Ltd. Brad Ohler is currently completing his fourth year of his geophysics degree at the University of Alberta. Upon completion, he will work for Shell Canada for the summer, then return to university for his MSc in geophysics. Some of Brad's interests include snowboarding, kayaking, and reading.



Bree Rees, 3rd year B.Sc. in Geology at the University of Regina sponsored by PennWest Energy Trust. I'm majoring in geology, and will be graduating in the Fall of 2010. I enjoying all aspects of geology but I am particularly interested in going into an exploration field of work or the coal industry when I graduate. Outside of my academic studies my personal interests include photography and going to movies.



Cameron Toy, 3rd year B.Sc. in Earth Science at the University of Waterloo sponsored by Pulse Data Inc. I am currently a third year student at the University of Waterloo majoring in earth science and specializing in geophysics. I enjoy my studies in earth science and am looking at continuing my education at the graduate level.

As a student of a co-op program I have had multiple opportunities to apply my knowledge in real-world environments, which are experiences that have only confirmed to me that I have chosen the right field to study and I look forward to becoming a professional geoscientist.



Chris Thompson, 2nd year of B.Sc. in Geophysics at the University of Calgary sponsored by Talisman Energy. Chris Thompson was born and grew up in Kelowna, British Columbia. During his years in Jr. High and High school, Chris enthusiastically participated in the school band. He developed his love of music and immediately

connected with the piano, focusing on an interest in both Jazz and Classical styles of music. Chris enjoys skiing in the Canadian Rockies, playing squash, and practicing piano. He also has a growing interest in both travel and the culinary arts. After moving to Calgary at the age of fifteen Chris became interested in geosciences. He attended a job shadow with a professional geophysicist and this passion of earth sciences grew further. It was at this point Chris decided to enroll at the University of Calgary's geosciences department, where he will be completing a five year combined degree program in geophysics and geology. Chris is currently in his second year and looking forward to a career in the oil and gas geosciences field.

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CSEG Scholarships

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Danielle Anne Mountjoy, 3rd year of B.Sc. in Geophysics at the University of Victoria sponsored by Zokero Inc. (Seisware). I am a 3rd year honours student in the Earth Science department at the University of Victoria. My work term with EnCana during the summer of 2009 was my first taste of the industry and this experience sparked an interest for oil and gas exploration.

The fast pace environment and the many avenues for learning kept me continuously intrigued and driven. I am passionate about the outdoors; running, biking, and yoga fill my spare time and add balance to my life. The summer in the mountains was awesome; it provided a great playground for many hikes and camping trips. Next year I will be doing my honours thesis and after I graduate I intend to work toward my professional registration. Being a dual Canadian-Australian citizen, I plan to go to graduate school in Western Australia. I feel very honoured to be a recipient of the CSEG scholarship and would like to thank everyone involved for their consideration and generosity.



Dunia Blanco, Ph.D student at the University of Alberta sponsored by Arcis Corporation. I am from Colombia and my passion for Physics and Nature lead me to follow an academic degree in Geophysics. My principal research interest is Earth's magnetic field. I think that this is one of the most interesting and fundamental characteristic of the planet and its understanding is of

great importance to comprehend the evolution and future of the Earth. I am interested in the evolution in time of the magnetic, using experimental data. For this purpose I am working with the Paleomagnetism and Petromagnetism group of the University.



Farshid Forouhideh, Final year of M.Sc. Geophysics at the University of Calgary sponsored by EOG Resources Canada. Farshid received his first B.Sc. in Civil Engineering from Azad University, Central Tehran Campus, Iran. After discovering geophysics, he obtained his second B.Sc. degree in geophysics from University of Western Ontario, in London,

Ontario. He followed Dr. David Eaton to the University of Calgary and started his Master's in geophysics in September 2008. His research is focused on studying microseismicity induced by fluid injection e.g. in hydraulic fracturing, or in geologic sequestration of carbon dioxide. In particular, he will perform moment tensor and spectral analysis on microseismic data to delineate the slip mechanism and to characterize the reservoir in terms of stress field, fracture systems and migration/leakage patterns.



Frank Ryan, 3rd year of B.Sc. in Earth Science at Memorial University sponsored by Boyd Petro Search. My concentration is in petroleum geophysics and I am also interested in soft rock stratigraphy. I am the president of the undergraduate earth sciences student society (Alexander Murray Geological Club), as well I am a Memorial Ambassador. In my spare time

I play hockey, guitar and I enjoy the outdoors, as well as volunteer in the community. I am breaking into the energy industry this summer with an internship.



Ismael Ver-Rodriguez, 2nd year of an M.Sc. program at the University of Alberta sponsored by the Bob Won Trust Fund. I was born in Mexico City. I received my diploma in Geophysical Engineering from UNAM in 2004. After graduation, I worked for Schlumberger for 4 years, where I learned important concepts relative to processing and interpretation of VSP as well as microseismic techniques. In 2008, I decided to return to academia to pursue a Masters degree. This took me to the department of Physics at the University of Alberta. Last year I transferred to the PhD program. My research interests are in the area of signal processing and inversion.



Jennifer Fohring, 2nd year B.Sc. geophysics student at the University of British Columbia sponsored by Canadian Natural Resources.

No bio available.



Joel Kotkas, final year of B.Sc. program in geophysics at the University of Calgary sponsored by John Peirce and GEDCO. Upon graduation in April 2010 I plan to work at Tundra Oil and Gas Ltd., with a major role in reservoir characterization. I have recently attended the Reservoir Characterization Project at the Colorado School of Mines to expand the breadth and depth of my knowledge in this field. Outside of school and work I enjoy being challenged at any new activity and participate in most outdoor sports along with playing basketball year-round. I am an active member of the CSEG Student Outreach committee and was a principal organizer of the first annual CSEG Student Industry Field Trip. I would like to thank the CSEG, GEDCO, and John Pierce for their sponsorship to allow me to further my career in geophysics.



John Mosquera, M.Sc. in at the University of Waterloo sponsored by Matrix Geoservices Ltd. My academic interests lie in the integration of geophysical techniques and hydrogeology, and I am pursuing this at the University of Waterloo. My current research involves the use of ground penetrating radar (GPR), and its utility in identifying and monitoring contaminant plumes in and above the water table. Earlier research has demonstrated that GPR profiling is a promising non-invasive method for use at NAPL contaminated sites. Therefore, the use of GPR has far reaching implications for ground remediation strategies, developing remediation technologies, and protecting aquifers from contamination. Upon completion of my M.Sc., I hope to pursue a career with an environmental consulting company, utilizing GPR and my knowledge of hydrogeology to identify and remediate contaminated sites.

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CSEG Scholarships

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Lisa Fodor, 2nd year of B.Sc. in Earth and Ocean Sciences at the University of Victoria sponsored by the Popilchak Trust Fund. Hello, my name is Lisa Fodor and I am in my second year at the University of Victoria. I am working towards a BSc in Earth and Ocean Science. I grew up on a farm east of Red Deer, Alberta and was a member of the East Lacombe Beef 4-H club for five years. During my last year I held the clubs secretary position. I enjoy hiking, soccer, snowboarding and golf. I would enjoy a career in earth science with equal amounts of field and laboratory work.



Raminder Singh Samra, B.Sc. Physics at the University of British Columbia sponsored by Sigma Exploration and Appoterra Seismic Processing. First of all I would like to thank the CSEG for awarding the scholarship to myself, this award means a lot and will greatly assist my future plans in becoming a geophysicist. Recently I graduated from the University of British Columbia with a Bachelor's degree majoring in Physics with a minor in Earth and Ocean Sciences but the core of the degree was focused around geophysics and astronomy. As of May 2009 I have been working part time as a research assistant performing seismic velocity measurements upon anisotropic rocks at the UBC Seismic Velocity Lab. I also hold a part time position as the resident astronomer at the HR Macmillan Space Centre in Vancouver. After this year I plan on entering graduate school preferably studying geophysics.



Sean Contenti, M.Sc. Geophysics at the University of Alberta sponsored by Devon Canada Corporation. Sean Contenti received his B.Sc. in geophysics from the University of Alberta in 2009, and is currently pursuing an M.Sc. degree from the University of Alberta. His research is focused on seismic analysis and migration applied to teleseismic earthquake data. He is also a member of the CSEG, and a Geoph.I.T. with APEGGA.



Wesley Kasha, Final year B.Sc. Geophysics at the University of Alberta sponsored by Nexen Inc. I am currently studying as a full time student at the University of Alberta, and I will be graduating in the spring of 2010 with a BSc. Specialization in Geophysics degree. I maintain a lifelong passion for applied geophysics, and I am actively pursuing a career related to geophysical exploration and interpretation, possibly geared towards the environmental aspects of Geophysics. I have always been fascinated with the earth beneath my feet, and this is demonstrated not only through my keen interest in Geophysics, but also in my active lifestyle as an avid backcountry hiker, skier, and rock climber. I am considering working for a year or two as a junior Geophysicist before returning to the University of Alberta to complete a Masters degree in Integrated Petroleum Geoscience.



Zabi Werdeg, 4th year of B.Sc. Program at the University of Calgary sponsored by the Chris Elms Trust Fund. I am a fourth year geophysics honors student with a minor in geology. Currently I am finishing courses in seismic processing and computer programming. I am involved with many organizations both on campus and off. In addition to my involvement with GUSS (Geophysics Undergraduate Students' Society) as a fourth executive I have been involved with the AIDs awareness club as VP of events for an organization that helps raise awareness about the effect of AIDs both domestically and globally. I like to keep active by being involved in a coed soccer league, hiking, weight training and of course hockey. I am also working on my honors thesis which involves analyzing the effect of fractures on SH waves by applying already introduced seismic processing models such as Haskell-Thompson. My career aspirations are to work in the oil and gas industry where I can apply my geophysical and geological knowledge to actual industry related cases.

CSEG Scholarship Committee Contact Information:

Dennis Melrose (Nexen Inc.),
Email: damelrose@nexeninc.com
Phone: 403-699-4000

Hassan Odhwani (Divestco),
Email: Hassan.Odhwani@divestco.com
Phone: 403-298-5685

Matthew Klukas
(Talisman),
Email:
MKLUKAS@
talisman-energy
.com 



Column Contributor
Carmen Swalwell

Swalwell Resource Consulting
Phone: 403-560-8431
email: carmen_swalwell@yahoo.com

Just a reminder about the upcoming SEG convention in October. If

companies do not have your contact information, they can't invite you to convention events. So send in your information and I will publish it in the June issue.

Thank you for all the people that congratulated Kelly and I on our marriage. It is appreciated.

Does anyone want to promote their charity? If so, please contact me. This is a great opportunity to educate people on a charity that is close to your heart. Who knows? You may even inspire someone to volunteer.

If you have a new job, been promoted, retired, or want to share your contact information, you can contact me at carmen.swalwell@shaw.ca or 403-560-8431.

ON THE MOVE...

Earth Signal Processing Ltd. is pleased to announce that **Alberto Galleguillos** has joined the ESP team in the capacity of Business Development. Alberto brings a wealth of technical knowledge, as well as extensive processing experience in both domestic and international markets. Alberto can be reached at 403-264-8722 or by email at alberto@earthsignal.com

Olympic Seismic Ltd. is pleased to announce the addition of 3 new staff:

Greg Clearwater –

Account Receivables Specialist

Greg was previously with a major Wireline company where he was the Accounts Receivable and Accounts Payable Coordinator. Greg brings with him 8 years of experience in the Oil and Gas Industry. Greg's new contact information is as follows; phone: 403-515-5870 email: clearwater@olysei.com

Irene Lane – Executive Assistant / Operations Administrator

Irene was formerly with Ultraline Services Corporation for 5 years and brings with her over a decade of experience in the Oil & Gas Industry. Irene's new contact information is as follows; phone: 403.515.5659 email: ilane@olysei.com

Cindy Statham –

Support Services Technician

Cindy's 10+ years of experience in the Oil and Gas Industry experience include Seisview / Divestco and Arcis where she was subcontracted out to Devon Canada. Cindy's new contact information is as follows; phone: 403.515.5650 email: cstatham@olysei.com

Olympic Seismic is also pleased to announce the promotion of **Jude Affonso** to Senior Vice President, Finance / HR and **Mark Watson** to Senior Vice President, Operations.

Arcis Corporation is pleased to announce the appointment of **Mr. Mike Perz, M.Sc., P.Geoph.** to Manager Technology & Integration. Mike achieved his B.Sc. in Physics from University of Toronto in 1990 and his M.Sc. in Geophysics from University of British Columbia in 1993. His work career started at Pulsonic Geophysical Ltd. where he worked as a geophysical

applications programmer from 1993 to 1997. Mike then joined Geo-X Systems Ltd. (now Divestco Inc.) in a similar position until 2004 at which time he was promoted to Manager, Research and Development.

Mike joined the Arcis team on April 1st, 2010 and will be involved in the continued development of Arcis' high level proprietary geophysical software. As an active member of Arcis' management team, Mike will also be involved in developing our people resources and in managing the growth and development of our global business.

Mike can be reached at mperz@arcis.com or by calling (403) 781-1700.

Absolute Imaging Inc. is extremely pleased to announce that **Jo-Anne MacLeod** has joined their organization as a Senior Seismic Data Processor. Jo-Anne would like to let friends and colleagues know that she can be reached at joanne@absoluteimaging.ca or 403.806.6733.

Carl Reine would like to announce that he has joined Nexen Inc. as a Geophysicist in the Shale Gas group. Carl has recently returned from the UK after successfully completing his Ph.D. in geophysics at the University of Leeds, and is looking forward to re-joining the workforce. He can be reached at 403-699-5052 or carl_reine@nexeninc.com

THE STORK HAS ARRIVED...

Curtis Kramchynski (Consultant) and **Lisa Eastman** (Geotir) are both so excited to announce the arrival of their new baby boy **Owen Samuel Kramchynski**. He was born on January 28, 2010 weighing in at 8lb 12oz. His big brother Kelly and big sister Andie are thrilled with the addition of a new playmate. **R**



Graham Millington, P.Geoph. (1947-2009)

A geophysicist who was a friend to many of us, always had a twinkle in his eye, and loved sailing and skiing, is no longer with us. **Dr. Graham Frederick Millington, P. Geoph.**, passed away on October 15, 2009, at the age of 62, after a short battle with cancer.

Graham was born in Urmston, Lancashire, U.K., and completed his undergraduate work in Physics (B.Sc. Sp. Hons.) at Bristol. Shortly thereafter he moved to Canada and completed a Ph.D. in Physics at Queen's University in Kingston, Ontario (1973). He moved west to Calgary and joined Veritas Seismic Processors in 1975 where, with his enquiring mind, his always ready wit and his charm, he quickly learned how to write software to process seismic data and later how to manage a department specializing in seismic inversion.

After leaving Veritas, Graham had a short stint at Petrel Consultants and then joined Canadian Superior Oil in 1982 (later Mobil Oil Canada – 1986), where he stayed for most of his career. While with Mobil he enjoyed postings in Dallas and London and back to Calgary, working in a variety of technical roles, including Area Exploration Manager for Central and Northern North Sea. He was Geoscience Coordinator and then Manager of Technical Services, with a return to Calgary in 1998. He directed the licensing of Mobil's High Fidelity Vibratory Seismic (HFVS) technology to Enertec, a technology innovation of considerable interest to those in the WCSB.

In 2001, Graham retired from ExxonMobil and worked as a consultant



doing 3D seismic survey designs for Complete Land Services and Complete Exploration Services. He also advised the Federal Government on Scientific Research and Experimental Development matters relating to conventional and heavy oil research.

While in Calgary, Graham was heavily involved in the CSEG, serving as Editor of the CSEG Journal (1980-1983), as Sponsorship Chair for the 1997 CSEG Convention and for Geocanda 2000, and chaired the CSEG Chief Geophysicists' Forum (2001-2004). Graham was CSEG Technical Co-Chair with John Peirce (CGU) for the 1985 CSEG/CGU Convention. Graham always had a quip to lighten long technical meetings and a keen sense of getting the job done right.

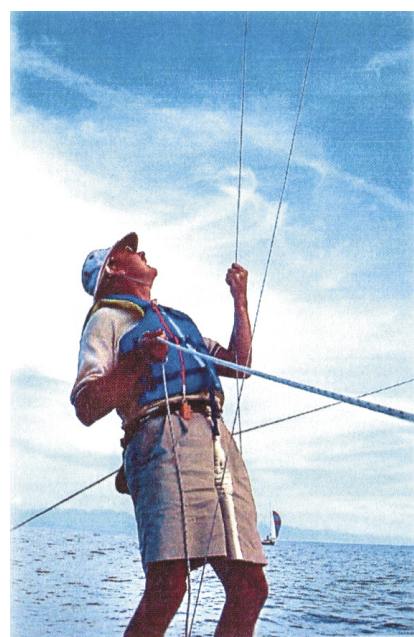
In 2004 Graham and his wife, Anne, made a positive choice to do less geophysics and move to the West Coast, taking up residence on Protection Island in Nanaimo, BC. Graham developed a keen interest in sailing and lived to be on the water. Graham and Anne also maintained

their interest in the mountains and shared ownership in a condo in Windermere. Graham also loved skiing but only tolerated his nemesis, golf.

Graham is survived by his wife Anne, a geologist also well known in our geoscience community, and his son Kevin and daughter, Beth. A celebration of his life was held Oct. 25, 2009, on Protection Island in their small community centre, packed with friends. Some of Graham's ashes will be spread by Lake Windermere this May.

We celebrate Graham's life and the many positive influences and lasting friendships that he made.

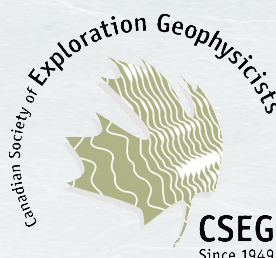
*Submitted by John Peirce,
with Brock Hassell, and Mike Galbraith*



Have you moved?

**Do you know someone
who has moved?**

Let us know



Jim Racette
Managing Director, CSEG
Tel: 403 262 0015
Fax: 403 262 7383
Email: cseg.office@shaw.ca



Column Contributor
Lorna Engleson
 CGGVeritas – Canada Data Library
 Phone: 403-205-6134
 email: lorna.engleson@cggveritas.com

May 2010 – Lorna Engleson is off to have a baby, so I am back on Grapevine duty for a few months! This month, I would like to highlight the activities of David MacKidd (EnCana), who has been active with “Inn From The Cold”

since its inception in Calgary back in 1997. Inn From The Cold, created to provide emergency assistance to families in need, started from one church, and has now grown to include support from many multi-denominational churches/synagogues and community groups. These days, Dave organizes teams to cook dinner at the new Emergency Family Centre located in the Beltline district in Calgary. If you, or your company, may be interested in volunteering one evening (as an individual or as a team-building activity), please check out www.innfromthecold.org or contact Dave directly at david.mackidd@encana.com

If you have any news for the Grapevine, you may contact me at Kristy.manchul@cggveritas.com or 403.205.6243.

2nd ANNUAL CSEG T-Wave TOURNEY

Come join us for a fun and relaxing day of golf with your fellow colleagues. 2009 was a tough year for a lot of the companies and people in our industry. As a committee, we tried to keep the focus on having a fun tournament where people would socialize and golf would just be a bonus !

Where: **Inglewood Golf and Curling Club**
 Date: **Monday June 14th, 2010**
 Tournament
 Format: **Modified Texas Scramble,
 shotgun start at 1:30 p.m.**

This is a fun tournament open to all CSEG members. Registration includes a Dinner, Green Fees, Power Carts and Prizes. 50/50's will once again be sold with the proceeds going to the Kids in Science Project.

Registration and Sponsorship information is available on the CSEG website.

SAVE THE DATE! WiSE TOURNAMENT 2010

The annual Women in Seismic Golf Tournament will be held on **Monday, August 9th**, at the Fox Hollow Golf Course in Calgary. Every year, 144 women get together to enjoy a day of golfing, networking and raising money for the **Alberta Cancer Foundation** (with proceeds raised going to programs for Cervical and Breast Cancer initiatives).

Registration will begin soon. Stay tuned!

If anyone is interested in sponsorship, volunteering on the WiSE committee or donating team/individual prizes, please contact Danielle Harrison at Danielle.harrison@divestco.com or call 403.770.0359.

58th ANNUAL DOODLEBUG GOLF TOURNAMENT – DATE & LOCATION CHANGE!

This year there are some big changes in store for the tournament. The Doodlebug Golf Committee values the input from the CSEG membership and their associated companies. For this reason there is a new location and date for the 2010 Doodlebug.

September 9 – 11, 2010, at the Kimberley Alpine Resort.

The Doodlebug Golf Tournament is an event held each summer that provides a competitive golf venue for CSEG members of all levels and ability, from scratch golfers to true first-timers. Participants and their guests will enjoy a full schedule of formal and informal social events throughout each day and on into the evenings. Similar to Doodlespiel and Ski Spree, it is the social and networking aspect of this event that provides the basis for a great weekend amongst new and old friends of the Canadian Geophysical Industry.

Kimberley Alpine Resort is one of Canada's premier resorts that offers Doodlebug participants access to this fantastic venue at a very reasonable cost. The golf course is challenging, but extremely forgiving and each hole bears a different and distinctive view of the majestic Kootenay Range.

The 2010 Committee hopes that you will consider this event in your plans for this summer. www.doodlebuggolf.com

DIRECT DIGITAL ONLINE INC.

Direct Digital Online Inc. is pleased to announce that their seismic data management services are now available. Working with its joint venture partner **Accu-Audit** and using the SeisInfo platform **D.D.O.** will be offering an accurate and cost effective solution to seismic data management. For more information please contact **Pat Shannon** (pshannon@direct-digital.com) or **Tammy Bauer** (tbauer@direct-digital.com) at 403.265.6886.

Direct Digital Online Inc. a subsidiary of **Absolute Imaging Inc.** offers comprehensive and diverse services including disaster recovery, reproduction and data management.

LIGHT UP THE WORLD

Light Up The World would like to thank the many companies and individuals who donated items to the GeoCanada 2010 Convention Silent Auction. The money raised helps LUTW to provide renewable energy technologies and high efficiency lighting to communities around the world. Your support is greatly appreciated.

In the interest of promoting sustainable development LUTW has invited Bob Willard, a leading expert on corporate sustainability strategies, to speak at The Ranchman's Club at noon on June 4th. For more information please visit www.lutw.org

*(Columnist note: I would like to commend **Sean Callaghan**, LUTW/GeoCanada 2010 Silent Auction Coordinator, for all of his hard work in putting the Silent Auction together. He and his team have worked hard in soliciting donations, which admittedly in these economic times CAN be a bit difficult. PLEASE visit the LUTW*

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CSEG New Members

Alhani, Ahmed Student	Kasha, Wesley Student
Blanco, Dunia Student	Phillips, Nigel Mira Geoscience
Budd, Cassandra Student	Sookdeo, Shane Student
Dalsin, Jillian Student	Newman, Austin Student
Deck, Irvin CGG Veritas	Reid, Pamela Nexen Inc.
deMilliano, Brendan Student	Rohraff, Karol Student
Deutscher, Greg Student	Sanguinetti, Rafael Consultant
Grifi, Meriem University of Western Ontario	Shamsa, Amir Student
Guo, Richard Geoseis	Sookdeo, Shane Student
Harvey, Stephen Student	Taylor, Steve Student
Hess, Scott Statoil	Tomberlin, Timothy ConocoPhillips
Jaradat, Awni Sproule Associates	Vera, Virginai Student
Jonasson, Jordan Student	Zhao, John Schlumberger

Grapevine...

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*auction on the Convention Exhibit floor
May 10th and 11th.)*

FUGRO

Fugro Selects OpenSpirit as Corporate-level Integration Solution.

Fugro has signed a corporate-level Business Partner Agreement to leverage the OpenSpirit interoperability framework across their family of companies and products. Fugro Data Solutions and Fugro-Jason will be the first of the Fugro companies to take advantage of the OpenSpirit SDK.

The OpenSpirit framework will enhance Fugro's ability to streamline data search and transfer between applications and data stores, resulting in increased efficiency and productivity for data management and geoscience staff and reducing overall IT and data management costs.

For more information contact: **Leonard Hendrix**, Fugro Data Solutions (Canada) at 403.240.7885 or leonard.hendricks@fugro-data.ca 