The future of geophysics in Canada’s oil and gas industry

The role of geophysics within the Calgary-based oil and gas industry is currently in a state of transition. Declining conventional reserves and the emergence of resource plays have created a different set of geo-technical challenges, and the discipline of geophysics within this newly emerging business environment is redefining itself. The demand for traditional forms of seismic interpretation is waning, and geophysics needs to find new ways to add value. Elsewhere in this issue of the Recorder, “Quantitative Interpretation Part I: Method” by Hunt et al provides excellent examples of how this is actually happening in an applied sense.

In an effort to understand where we are headed in a more general business sense, the Recorder posed a number of forward-looking questions to members of the CGF (Chief Geophysicists’ Forum). Their responses below capture some strong consensus opinions, plus a broad range of other interesting perspectives.

What direction(s) is the role of the geophysicist likely to evolve in?

Doug Uffen

In order to answer this question, I need to place my comments into context. In Canada, the geophysical industry has become bi-modal. Domestically, the geophysical science is being deployed in a development mode to help find reservoir “sweet spots” that will enhance deliverability and therefore directly impact the bottom line economically. Hence, all the sub-technologies associated with reservoir characterization and attribute analysis are the focus of these efforts. Deploying these sub-technologies is highly technically oriented and can be greatly rewarding, but it often places geophysicists in a service-like oriented role to what is essentially a “mining” operation, as companies harvest our resource in what is perceived to be a mature basin.

Internationally, our science is being deployed in an exploratory mode to hunt for large reserves, reduce capital risk exposure, and increase the chance of success of drilling. Structural knowledge, combined with our stratigraphic skills which have been honed by years of working within the WCSB, places geophysicists in a league of their own on the international stage. Our knowledge and abilities to understand subtle nuances of the seismic wavelet to image a channel sand, reef or bank edge is a skill set sought after throughout the world. Hence, our craft leads the exploration efforts as there is often not much well control and seismic data is more vital for reducing risk.

David Cooper

Traditionally we’ve used math and physics skills to understand how geophysical (and in particular, but not limited to, seismic) observations can be used to predict geological properties like structure, rock type, porosity, fluids etc. Obviously the complexity of our profession leads to wonderful details at our conventions, business meetings, etc., and amazing improvements in our methods have emerged. Along the way we’ve become involved in financial and business discussions, well beyond our typical rock and fluid discussions.

Going forward, either:

a) We are facing commoditization, in which we pass off ‘non-integrated reports’ to consumer companies, potentially leading to increasing disappointment and decreasing relevance, or

b) we are facing distrust by, and complete irrelevance to a maturing industry in a maturing basin developing ‘resource plays’, or

c) we are facing technical challenges in engineering and resource extraction arenas, whose solutions can lead to ‘increasing relevance and prosperity for all’. ;-) The latter will require learning new languages (engineering and geophysics both deal with physics, but often our historical descriptions cloud the real common physics from us). And we will face solving new uncertainties, not the least of which are in the engineering beliefs that what is built by an engineer will work according to its design specifications. We can no more place implicit trust in an engineering design, than we can place implicit trust in a geological model. Honest technical dialogue will be paramount.

Using the medical analogy of, ‘Let’s look, then cut’, I can see the geophysicists’ role being augmented by, ‘Let’s review how well that worked’ and, ‘Let’s monitor for defects in our operations’. Where did others’ efforts fail; where can we extract more value? This will guide the evolution of the role.

Penny Colton

Looking into the future, I can imagine geophysicists slotting into a few different roles, including:

• Engineering geophysicist, providing specific results-based quantization of information
• Signal innovator
• Classifier of maps

Marian Hanna

I can see the geophysicist role possibly becoming a contract permanent position within oil companies for specific tasks to

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be completed within a project, and more of a specialist role on the service side. I had this conversation in 1999 with Lord Brown, then CEO of BP. He said BP’s business successes were deeply rooted in their technical applications/successes and technical applications will continue to evolve in complexity. I can also see our geophysical world becoming even more of a higher scientific skills field, with all the bells and whistles as in the gaming industry, for complete integration of all data.

**Tooney Fink**

The complexity of the workflows increasingly being utilized may necessitate more ‘niche’ expertise; e.g. shale gas/oil specialists, microseismic specialists, heavy oil specialists, frontier basin specialists, processing/inversion specialists. A successful asset team will require the geophysicist to work closely and collaborate with geologists, reservoir engineers and drilling/completion engineers, plus economists.

**John Duhault**

I can see the role evolving into three directions:

- The pure geophysicist will likely evolve into a “service group” to the drilling operations of a company or be contracted out to identify geo-hazards via frac monitoring etc.
- The more versatile geophysicist will help guide resource play development and help fine-tune the “edges” and “sweet spots” of these plays as they are pursued.
- The third will identify “conventional” plays that can be pursued using “unconventional techniques” in Canada and overseas.

**Kathleen Dorey**

The geophysicist is likely to evolve into a ‘geoscientist’ in the Canadian industry, more as a function of the maturity of the basin, as opposed to the increasing emphasis on unconventional resources. A successful geoscientist will be able to interface and understand additional concepts in reservoir engineering and geology in order to maximize the reserve and resource potential of a mature basin.

**Neil Orr**

Hopefully we can convincingly move from a largely exploration role to a shared production discipline as well.

The role will likely evolve from a mapper and hydrocarbon finder, to more of a technical consultant over the life cycle of a portfolio of assets.

There will be some continuing traditional geophysical work on the remaining conventional potential of the basin, and also increasingly on international assets being handled out of Calgary. This work will be defined by the basin being worked:

1. **Mature basins:** Exploration geophysics => reservoir geophysics => (tight reservoir geophysics, thermal reservoir geophysics)
2. **Immature basins:** Better exploration methods pertaining to Acquisition, Processing, Interpretation and the reduction of risk.

**Rob Kendall**

The geophysicist will be become more of a generalist with definitely more engineering knowledge. Traditional interpretation has been greatly affected by new interpretation tools and software and the modern geophysicist is able to explore a far more thorough list of exploration possibilities. Seismic data quality is also continually improving and the RISK associated with seismic is decreasing.

**James Alison**

The geophysicist will become the integrator of play information and ambassador of geophysics to the land of the drillers.

**Tom Sneddon**

Geophysicists will continue invading spaces currently occupied by geologists and engineers. This will proceed through enhancement of the asset team concept to include responsibilities for the full cycle of exploration, development, reservoir management and drainage improvement through to final abandonment.

**Ron Larson**

Geophysicists are likely to assume a geomechanics role with the objective of optimizing capital expenditure. Choosing acoustic terms over elastic terms for simplicity and framing the statements like a hypothesis it could be stated as: how sound travels through rock should be related to the sound rock makes when it is broken. In turn that sound should be related to how much effort it takes to break the rock. The ability to avoid hazards and positively affect unit production/unit capital is where geophysicists will be called upon to add value.

**Glenn Malcolm**

We are moving from exploration geophysics to exploitation geophysics whether we want to or not here in western Canada. Geophysicists will do better by going with the flow than trying to fight it, and should work on being familiar with the geology and engineering and being able to express their geophysical mapping work in terms that the geologists and engineers can relate to (i.e. depth, phi-h, etc.)

**Bill Goodway**

I see the geophysicist as being perfectly placed to evolve into the role of integrating elastic geologic properties of rocks to static geomechanical engineering attributes through the use of 3D AVO and azimuthal AVO inversion. This fits right into what I see as the future of both Canadian and US basins – the development and production of oil from tight shale source rock formations through horizontal well hydro-frac completions.

**Ken Mitchell**

By definition, geophysicists have always been problem solvers that rely upon physics, planetary science and geologic principles. Industrial applications of the discipline have largely focused on the identification and classification of anomalies. Although our future endeavours will continue to evolve and rely upon new innovation, the fundamental nature of geophysics will prevail.
The role of the most Calgary-based geophysicists into the future will fundamentally be to provide key insight to an integrated team of professionals with energy business objectives. We will continue to deliver the basic mapping of structure, stratigraphy and identification of anomalies. Increasing attention on rock physics anomalies that imply porosity, permeability, (and any preferred orientations of these), pore fluids and pore pressure variability are likely. These attempts to predict reservoir parameters from rock physics will require continual checking against data from other disciplines (geologic well logs, samples, core, drilling and completions data as well as production records.) While specific focus on such aspects as rock ductility, microseismic response and pore pressure prediction may increase, the fundamental role of geophysics is not likely to change. We will continue to measure and observe anomalies, then calibrate these with independent geologic and reservoir engineering data.

What technical skills are likely to be required by geophysicists in the future?

**Doug Uffen**

Domestically, to service the trends noted above, reservoir characterization skills, attribute analysis and computer software skills will be required technically. What I think is more important however are the business skills and project management skills as just being technically savvy will not be enough. Development requires business acumen.

Internationally, structural geology, stratigraphic skills and basin analysis are skill sets required. The business acumen is also required in this realm.

Young geophysicists may wish to consider obtaining an MBA in the future.

**Penny Colton**

For geophysicists to be employed by the Petroleum industry, I believe math, geology, and engineering skills will be required.

**Marian Hanna**

Required technical skills will include reservoir and fluid characterization skills, integration of all technical data (geological, petrophysical, geophysical, and engineering), reserves and resources, and business skills to name a few. Understanding of what we do as geophysicists and how geophysics adds value in the bigger economic picture is a very important perspective.

**Tooney Fink**

I believe knowledge around pre-stack seismic inversions for the purpose of extracting rock properties (especially for ‘unconventional’ reservoirs) will become increasingly important. Associated with this is a work flow that involves reviewing gathers in conjunction with one’s stack volumes, in order to look at far angle reflections, S:N and mutes.

I also see a working knowledge of microseismic monitoring becoming a standard requirement, and what critical bits of the drilling, completion and production parameters it can impact.

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**John Duhault**

I believe geophysicists will be required to have an understanding of seismic attributes and how they relate to the geology and reservoir engineering of the target horizon; they will need to have an understanding of sedimentology and stratigraphy, as well compressional and extensional tectonics; they will need to understand the value of geophysics in determining where not to drill (i.e. geo-hazard identification).

**Kathleen Dorey**

Geophysicists in the Canadian oil and gas industry will need to stay in-tune with the technical skills involved in unconventional resource type of plays. That is fracture detection (direct and indirect), anisotropy and its use in fracture detection, and other rock physics parameters useful in unconventional type targets. Just as important is knowledge and understanding of the math and physics behind the geophysical methods in order to sort out which geophysical methods are useful, and where they are best applied.

**Neil Orr**

Currently geophysicists need to relate traces (wiggles) to rocks. With growing unconventional oil and gas plays, we need to relate beyond rocks into reservoir physics. Future geophysicists will need a deeper understanding of the reservoir’s physical properties (porosity, temperature, pressure and fluid saturations) as they relate to their data.

Continuing requirements would include: integration with geology, horizon interpretation and mapping, seismic stratigraphic interpretation with synthetics, routine use of workstations, attribute analysis, and depth conversion and migration.

There will be an increasing focus on: integration with reservoir engineering, reservoir and fluid property prediction from multiple attributes, rock physics, quantitative interpretation, true 3D (voxel) workstation interpretation, time lapse interpretation, shear wave interpretation, microseismic.

Geophysicists will increasingly require skills in the areas of computer mapping, volume interpretation, multi-disciplinary skills, with the goal of integrating engineering, geology and geophysics. To be more specific, geophysicists will likely be required to:

- Understand the effectiveness of attribute analysis by cross-validating to desired reservoir parameters.
- Be able to perform very large scale integration studies with tools that are already evolving.
- Learn to work with digital data from all disciplines and integrate.
- Increasingly use non-seismic geophysics technology.

**David Cooper**

In addition to present requirements:

a) More lab and core testing skills
b) More engineering process and language skills

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C) More presentation and listening skills

Rob Kendall

Everything we already do plus timelapse seismic, microseismic, multicomponent seismic and geomechanical input.

Shawn Maxwell

With the expansion of unconventional resource plays, knowledge about hydraulic fracturing and reservoir engineering skills will become vital.

James Alison

It is the ongoing “ability to learn” new technical skills that is important. In the near term I see an ongoing need to have more petrophysics skills, and a better background in processing so that they can understand what has gone into the creation of the data they are interpreting.

Tom Sneddon

Whole earth physics will loom large for explorationists, thanks to passive methods, as will a sound knowledge of ray path tracing and fundamental optics. This will also require a sound knowledge of rock mechanics to allow practitioners to interpret in situ stresses and be able to predict formation fluid flow paths accurately. Critical thinking skills have always been important, but they will become ever more important as the volume of data increases and the quality of data becomes more important to confidently use it for advanced interpretation techniques.

Ron Larson

Increasing oil and gas industry focus on unconventional resources, and very tight reservoir plays means that geophysics will be less about locating the resource, and more about with helping to extract it efficiently. Extraction efficiency is directly related to elastic properties of the rock and that means we need to obtain both P- and S-wave data. In P-wave seismic processing terms, that means increased focus on accurate imaging (in combined VTI-HTI regimes), accurate pre-stack P-wave amplitudes and efficient pre-stack inversion. It should also mean increased use of shear wave seismic.

For E&P company geophysicists, the requirement is to understand P-wave structural imaging, as well as to understand AVO and pre-stack inversion as they relate to elastic behavior of the rocks as understood by the completions engineers. Attribute analysis as it relates to completions will be a standard deliverable for many projects. There is also an emerging requirement to understand passive seismic methods (microseismic) and, again, this understanding will be in terms of completion engineering. Layer time lapse analysis into that increasingly complex world (4D pre-stack inversion volumes of elastic constants) and a couple of trends appear.

First, seismic geophysics is evolving towards more elastic material science and less paleogeography and present day geometry. Second, and arising directly from the first, is staffing. One way or another, either by increasing their own staff, or by relying on staff in service companies, exploiters of ‘unconventional’ resources will need more geophysical personnel assigned to a project than they are traditionally accustomed to.

If one construes shale gas/oil, tight gas/oil, and very heavy oil (SAGD) as hydrocarbon mining, then the same skills can be assumed to be applicable to any subsurface mining operation. All mining has a similar economic goal: maximize product to market at the lowest cost (within regulatory and social license frameworks of course). That may be a good news story for the career options for young geophysicists. SPE paper #131779 (Unconventional Geophysics for Unconventional Plays, Rich and Ammerman, 2010) is an excellent summary of the skills that may be required in the future. While argument may arise over some of the details in the paper, the general direction of the narrative is both clear and important.

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Glenn Malcolm

I believe there will be more and more emphasis on looking at the complete waveform. For this you would need to be familiar with shear wave propagation, anisotropy, passive monitoring and fracture detection (open/closed, cemented/un-cemented, etc.)

Bill Goodway

I would encourage developing skills toward a general industry “standard” with broader disciplinary scope such as geoscientists as opposed to an isolated knowledge, experience or education in either geophysics or geology. As a consequence of this geophysicists need to become conversant and familiar with guiding geological principles and upgrade their geological knowledge in areas such as sequence stratigraphy and the hydrocarbon system from source to trap. On the other side geologists need to come to terms with the math-physics basis that underlies the seismic method so as to better evaluate the reliability of seismic data they interpret by necessity, as well as understanding what it represents and the limitations of this as a depiction of geology in outcrop.

Ken Mitchell

I won’t attempt to directly answer this question. Instead, I focus on the merits of a sound, basic B.Sc. curriculum and continuing education (see below). These will prepare earth scientists well to manage any future technical developments that challenge them. With new advancements in exploration geophysics, the trend of employers favouring M.Sc. graduates will likely become increasingly popular.

What areas of continuing education should geophysicists take to remain relevant and valuable?

Doug Uffen

I emphasize the addition of business skills, for geophysicists working domestically and / or internationally.

Penny Colton

I feel there is a broad spectrum of areas that geophysicists can and should continue to upgrade their skills in, including:

- Communication/business related software (Microsoft Word, PowerPoint, and Excel) as they keep changing and everyone should be up to date
- Website / network software for Webinar or related type presentations
- Engineering speak (philosophy, guidelines, geomechanics)
- Signal processing (attributes, geostatistics, core descriptions, downhole logging monitoring tools
- Geophysical interpretation tools, workflows (SEG E-Learning, Service Provider workshops, Training, Mapping)

Marian Hanna

Learning new technical applications will increase geophysicists’ marketability and the relevance of the geophysical or integrated technical application. Increasing knowledge of petrophysical, geological and engineering data and incorporation of all into geophysical data will be the future. I really believe the glue that will give a complete and integrated picture is geophysics. People skills, business classes and a few HR courses wouldn’t hurt. Public safety and job safety is also extremely important for their lives and the lives of others, especially with regard to APEGGA membership and that oath of protecting the public and the environment. An ethics course is always good too.

Tooney Fink

I think continuing education is an excellent way to become familiar with the various technical work-flows increasingly being employed, such as for pre-stack inversion. The detailed work required for these workflows is getting so complex; many geophysicists may not have the time or want/care to ‘master it all’.

John Duhault

I would emphasis microseismic, interpretation for unconventional reservoir and geo-hazards.

Kathleen Dorey

Anything to do with resource type plays, rock physics, water source and disposal methods and any additional environmental earth physics applications.

Neil Orr

Continuing education is an excellent way to keep up to date. Geophysicists should select courses based on their work and interests, and this will vary with the individual. Between the various consultant courses, DISC lectures, Doodletrain courses, and course vendors, an extremely wide selection is on offer, including:

- Rock physics (the bridge between traces and rocks)
- The effective use of post-stack and more importantly pre-stack attributes (AVO, AVAZ, etc.)
- The physics of tight gas reservoirs
- The mechanics of Frac’ing, etc.
- Integration of microseismic results with predicted continuum mechanics engineering models
- Cost effective 3C 3D seismic acquisition and their appropriate uses

David Cooper

Some effective areas of continuing education:

- cross-discipline graduate-level university evening courses (e.g. geomechanics, fractured reservoirs, thermal and other enhanced extraction processes)
- instruction regarding calibration at wells using borehole methods like VSP, compressional and shear sonics, anisotropy effects, geomechanical confining pressure effects, mineralogy effects, pore shape effects (weak and hyper-weak pores outvote their porosity fraction in terms of seismic impact)
- convention technical sessions dominated by people ‘wondering something’, as well as the exhibit floor and demonstrations dominated by people ‘selling something’

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The list of technical skills that may be required in the future offers plenty of scope for continuing education. Beyond the geophysical knowledge base, understanding in other areas is important. “Fundamentals” level courses in hydraulic fracturing, directional drilling, mining economics, materials handling and project management will be useful. Again, if one construes ‘unconventional’ as a mining operation, one of the challenges for a geophysicist in a ‘mining’ project is to effectively communicate with engineers. Geophysics and engineering have their own, somewhat mutually exclusive, dialects. It will be an ongoing challenge to make sure we’re speaking in ways each can understand. For example, in language terms, many geophysicists speak geomechanics with an LMR accent, while completion engineers tend to speak geomechanics with a Young’s/Poisson’s accent. Continuing education can help us communicate.

Shawn Maxwell
Practical geomechanics and in particular the integration between geophysics and engineering.

James Alison
I recommend whatever areas of continuing education that keeps the passion for learning alive. Soft skills training is also important to keep geo’s effective.

Tom Sneddon
Geophysicists will be drawn more and more into reservoir analysis and evaluation. Critical advanced knowledge of resource economics; reservoir modelling and reservoir mechanics will be needed in day to day practice.

Ron Larson
The list of technical skills that may be required in the future offers plenty of scope for continuing education. Beyond the geophysical knowledge base, understanding in other areas is important. “Fundamentals” level courses in hydraulic fracturing, directional drilling, mining economics, materials handling and project management will be useful. Again, if one construes ‘unconventional’ as a mining operation, one of the challenges for a geophysicist in a ‘mining’ project is to effectively communicate with engineers. Geophysics and engineering have their own, somewhat mutually exclusive, dialects. It will be an ongoing challenge to make sure we’re speaking in ways each can understand. For example, in language terms, many geophysicists speak geomechanics with an LMR accent, while completion engineers tend to speak geomechanics with a Young’s/Poisson’s accent. Continuing education can help us communicate.

Glenn Malcolm
I recommend that geophysicists stay current with new acquisition designs and especially developments in processing to use the whole waveform to extract reservoir parameters.

Bill Goodway
Geoscientists need to take engineering courses on unconventional drilling, completions and production. This is especially important in reserves booking for emerging tight gas and oil plays that can be uneconomic if development wells are located in formations that underperform due to very high decline rates, thereby leading to a continued waste of capital in the false expectation that time will correct the situation.

Ken Mitchell
Continuing Education opportunities for geophysicists – whether still in undergrad or seasoned professional can be quite similar. Augmentation of a good physical science education could be relevant where exposure to cross training is considered. Investigation of economic risk analysis, capital market regulation and operation, basic accounting and financial statement literacy are worthy business focus areas. Staying abreast of earth science developments may include field schools in depositional processes (including issues of diagenesis, porosity modification, permeability enhancement, hydrocarbon sourcing and migration or even basement heredity) as well as structural evolution and subsequent deformation. Project management and logistics planning will likely become even more important in the future as coordination and collaboration with other disciplines, regulators, local interests and “the field” (where the rubber meets the road) become increasingly important. Writing skills that support submission to regulatory bodies, making presentations to secure funding (to “management” or investors) or secure stakeholder acceptance have always been important. There is reasonable expectation that the importance of these skills will only become more acute.

More specific to our own discipline, the geophysicist of the future will need to rely on good, current science. As geophysical data processing techniques or “new” methods like microseismic evolve and advance, independent investigation will be relevant to assess their merits and application. Good understanding of science will guide geophysicists to select those technologies that truly offer added insight to their work. Where geophysicists find their careers focusing on a localized, seismic-based practice, consideration of study of other world basins and non-seismic techniques may be warranted. Therefore continuing education within our own field will need to be responsive and adaptive to new developments and applications of geophysics.

In order to handle an exponential increase in data volume to be analyzed, the geophysicist of the future, aided by service company providers, will rely even more on computer applications to speed workflows. Hands-on training to stay abreast of these methods will be an asset.

Data volume is already growing quickly as more 3C recording and prestack interpretation is taking place. Effective digestion of full waveform data demands good data management and manipulation tools. Microseismic recording is a further example of explosive data-volume increase that will require new tools to make it most
effective. Meanwhile, new interpolation algorithms offer considerable advantage to our statistically-based seismic data processing flows, but also make demands upon our array processors, available memory and similar computer capabilities.

Interpretation software that generates a multitude of attributes, cross plots and anomaly-generators are welcome innovations. They also create demands for data management, categorization and discrimination. Geophysicists in the future will have many tools available, but they will also need to be able to analyze and discriminate to determine which computations and criteria are most relevant. Therefore, continuing education that keeps the geophysicist up to data on interpretation platforms and workflows will be in order.

What is the business future of this basin, especially as it pertains to the application of geophysics?

Penny Colton

In business terms this basin is relatively mature, so companies will focus on business structures and strategies that will produce profits in this environment. Geophysics can play a role in this scenario by assisting in the monitoring of production efficiency when sweeping aging reservoirs with production.

Marian Hanna

Geophysics can provide better integration of technical data so that the leading industry advances (e.g. horizontal drilling, hydraulic fracturing) benefit from seismic predictions. It can also help with environmental issues, hazards, etc. As I’ve seen in other mature basins, new technology always yields access to previously unattainable areas, and reserves, etc. e.g. Shell’s deep water drilling record in the Gulf of Mexico. Technology usually develops as challenges present themselves and feasible economics opens the door. I’m banking on great things coming out of the WCSB and Canada. I enjoy visiting Houston but Canada is where we want to stay. (Besides, we need a positive movie to represent the oil and gas industry in Canada and I know some great Canadian actors who would love to be in such a film.)

Tooney Fink

The ‘deep basin’ portions of the WCSB foredeep, where pervasive gas/oil saturation exists; as well as the oil sands (Athabasca Basin +) will profit from continuous 3D seismic coverage, which in turn could profit from 4D coverage over heavily developed producing areas. Some existing spec 3D covered areas will need to be re-acquired with higher quality/denser surveys. Heavily developed producing areas (with lots of pad drilling schemes) may see ‘permanent’ installation of microseismic monitoring arrays. I think our industry can keep busy for quite some time.

John Duhault

Geophysics will be needed to minimize geo-hazards, conventional reservoirs will come back once the “unconventional” resources hit the “economic wall”. Data integration will be a key function for geophysicists, as well as aquifer mapping for shallow sources of water for human consumption and frac’ing.

Kathleen Dorey

The business future of the Canadian basin is unconventional types of exploration and development. This also includes going back to conventional areas and using new imaging techniques (such as AVO, AVAZ, curvature analysis, geo-modeling) to exploit the conventional and unconventional resources remaining. There is also an increasing demand for water source and disposal options with horizontal wells and frac’ing. Conventional seismic geophysical methods as well as alternative geophysical methods such as electro-magnetic techniques will be increasingly used in these areas. There is already an increase in demand for frac proppant sourcing in which mining geophysical applications may be required.

Not to be forgotten is the increasing demand for geophysical expertise sourced in Canada. Although the Canadian basin is maturing, there is an increase in demand for Canadian technology and knowledge to be used worldwide. Canadian land processing software, land acquisition methods and interpretation techniques are recognized worldwide. At Petrel Robertson, we have International clients that have specifically requested Canadian geoscience expertise for their exploration and development properties. Increasingly, international companies are being based in Calgary for this reason. This bodes well for the future of Canadian geophysicists and geoscientists in general.

Neil Orr

Unfortunately, with the advent of unconventional plays, we seem to be moving into a business model where fewer geophysicists may be required. In such environment the generalists may have an advantage over the specialists.

Drilling is shifting from conventional to unconventional targets. Geophysics for conventional exploration and development is focused on mapping structures and amplitudes, and occurs mainly before the asset is placed on stream. Geophysics for unconventional resources adds additional applications and occurs over the producing life of the asset. Examples of additional applications include: geo-hazard identification and avoidance, maximum reservoir contact horizontal well planning, microseismic, time lapse seismic monitoring, and geomodel inputs.

Of course, the development of resource plays - Shale Gas, Tight Gas/Oil, Thermal - is a business trend that is likely to dominate for the longer term. What role will geophysics play in optimizing the development of these resource plays? It can develop a lead role in defining and measuring key geophysical parameters that affect production efficiencies in regional play fairways, and how they would collaborate with geological, and possibly engineering data. For example:

- Regional stress regime \( \leftrightarrow \) fracture density, Horizontal, Vertical Vel. anisotropy \( \leftrightarrow \) [fracture distribution, pore geometry etc.] \( \leftrightarrow \) production, recovery, etc.
- Micro seismic analysis has a presence, but will provide only a support role to engineering.

David Cooper

We face “commoditization”, or worse, irrelevance in this maturing basin. However, the basin needs our expanded skills in optimizing
resource extraction, because engineered processes do not work in the ‘real world’ as effectively as in the engineering design. We can add value by monitoring for unswept hydrocarbons, and for misplaced or ineffective injection, and this will almost certainly grow in relevance.

**Rob Kendall**

I believe bumps on highs and traditional strat plays will continue to be important at $100/bbl. However the resource play is what is going to ultimately sculpt the future for our basin.

**James Alison**

I am very optimistic about the business future of the WCB.

**Tom Sneddon**

The WCSB has always been quirky and demands a lot of imagination on the part of interpreters. History over the past half century instructs that each replacement barrel is harder to find and produce and thus more challenging from a business perspective. This trend will continue for at least another half century. Investment into new technology must be part of every new business plan, as must a continuing awareness of new advances in science. It will be through a constantly improving understanding of earth physics and geoscience technology that will keep our companies vital and in business.

**Ron Larson**

Shale gas requires large amounts of capital. Increasing shale gas activity implies large capital expenditure by large(ish) companies. With large amounts of capital directed towards ‘resource plays’ two things probably happen to the geophysics world:

1) More geophysicists on both the service side and the E&P side work fewer numbers of unconventional projects (and relatively small amounts of data), but they work them much more extensively, and

2) the application of resources, both capital and people, on unconventional plays opens opportunity for smaller players to re-enter the conventional oil and gas world. If the focus on unconventional can be viewed as a ‘downturn’ in conventional activity, then the industry will probably experience what it has seen arise from most downturns – a minor repatriation of the oil and gas industry as smaller local companies build on the void left by larger, typically ‘offshore’ companies.

Both of these possible trends offer hope for the future. Gas price remains a concern, but potential developments in west coast LNG terminals (Kitimat and others) offer promise of a more global gas market with oil equivalent pricing.

**Glenn Malcolm**

Exploitation is here to stay. We need to tailor our geophysical expertise towards defining the development of reserves and the best way to exploit them (spacing of wells, fault location, sweep efficiency, narrowing the range of reserve estimates, etc.)

**Bill Goodway**

A major business trend I most definitely see is the exploration and development of unconventional tight oil or oil in shale source rocks such as the Bakken play that has exploded in North Dakota and to a lesser extent in Alberta and Saskatchewan. The USGS report estimates the amount of technically recoverable oil using technology readily available at the end of 2007 within the Bakken Formation of North Dakota and Montana at 3.0 to 4.3 billion barrels with a mean of 3.65 billion:


**Ken Mitchell**

In my opinion, the business future of the WCSB is quite promising. The petroleum system(s) present here will continue to be prolific. Consideration of economic limits will always be an influence, but as long as there are markets for hydrocarbons, WCSB can enjoy continued development. With the emergence of shale basins that are much closer to market, our localized activity does not operate in an economic vacuum. Therefore a global perspective and adaptability will be critical to success.

During the 1970’s concern over limits of energy supply abounded. At that same time, the prospect of producing energy from the hydrocarbon source kitchens would have been considered wacky. In recent years, Mannville coals, the Bakken, Duvernay and Colorado Group have created a renaissance of E&P activity. We should expect more attempts to exploit hydrocarbon source kitchens, shale gas, as well as tight/poor-quality reservoirs and even Proterozoic formations of Western Canada.

Consider that, at Cambrian time, much of northern Canada, eastern Siberia and western Australia were located in the same geologic neighbourhood, then subsequently overlain with a vast, regional evaporitic sequence. Massive hydrocarbon resource and reserve is well documented in eastern Siberian reservoirs of Cambrian and Precambrian age. Some debate over biogenic and non-biogenic gas within these fields continues. With production and confirmed reserves of 100’s of MMBO and 10’s of TCF of gas there is certainly incentive to consider analogues within the NWT of Canada.

While we pursue oil sands, heavy oil, tight oil and gas in a broad spectrum of the stratigraphic column, there is no reason to limit our prospects to the Phanerozoic strata.

The key to business success will not simply involve the technical exploitation of such resources, but to do so in an efficient manner that can deliver to markets at a competitive price.

Business issues specific to geophysics that will likely evolve in the future are numerous. There will be increased demands on our seismic data to deliver more detailed, full waveform information. Many areas of the WCSB that have already been extensively shot with 3D may have to be re-acquired. The 1990’s era P-wave parameters focused to Paleozoic targets may not support our future needs. The acquisition sampling at all stratigraphic depths can be significantly improved upon, with the upside of full waveform recording with richer azimuthal distribution. Since vintage 3D was
acquired, new surface development and provincial regulations may make new surveys challenging from a logistics, approval and stakeholder perspective. Meanwhile, our field acquisition business sector is facing a declining market, and shortages of skilled labour and advanced 3C equipment. The future stability of a healthy, cost-effective seismic acquisition contractor pool is a real concern.

What changes, if any, should be made to the core geophysical curriculum at the B.Sc. level?

Penny Colton

I'd like to see universities offer or include more co-op work experience.

Marian Hanna

I'd like universities to add an integrated course that includes a cross section of academic departments (Geoscience, Engineering, Business departments). The goal of such a course is to teach all students that this is a business and not a boondoggle or a science experiment that never ends. On the E&P side our job as geophysicists is to add reserves by successful implementation of scientific skills. In the course, give the students a budget and get them to go through the entire process from licensing land, shooting seismic, processing seismic, drilling wells and putting the wells on production while keeping track of budgets and economics. All teams compete against each other just like in the real world.

I've made this recommendation to 3 universities in the States USA and they implemented the course into their curriculum, with some resistance, of course. Industry participation is required for such a course design and many E&P companies do this internally or can help make it happen. Feedback I previously heard upon entering the field is that the university I attended put out students that knew what to do and why they were doing it for the business. That is very good for any university and their students. Most students (and people in general) could use some soft-skills such as on how to get their ideas across, how to deal with others, and appropriate ethical business behavior and attire. A little land business background and environmental training is also useful.

Tooney Fink

The integration of geophysics, geology and reservoir engineering continues to be critical, so a curriculum that achieves some of that would be beneficial. SIFT and GIFT style programs are very valuable.

Kathleen Dorey

I don't have any specific recommendations on this as I am not entirely up on core curriculums across Canada. However, I am increasingly impressed by the new graduates I am seeing coming out of the universities recently. This may be a function, in part, of the slower economy and seeing a lot of the best recent graduates still looking for work.

Neil Orr

Our two main universities graduating geophysicists (namely U of C and U of A) have very different approaches. At U of C, Geophysics is part of the Geosciences Department and students take courses in Geophysics early in their program. At U of A, Geophysics is part of the Department of Physics, and their students don't take core Geophysics courses until their third year. Both approaches serve a purpose and could benefit from adding Reservoir Geophysics to their curriculum.

New graduates from the current curriculum are quite well prepared and I don't believe any significant changes are necessary as Industry needs to take responsibility to specifically train new grads. Exercises and case studies within courses should be periodically updated to reflect current industry practice. U. of A. Integrated G&G one year Master's program needs further industry support and to more attract top students.

It is desirable for new graduates to have had two or more summer jobs or co-op terms in the industry, and companies should be proactive in providing these opportunities.

David Cooper

Integrated projects within the geological exploration domain will need to be augmented by engineering and reservoir development projects that involve all three disciplines. Increased training in rock properties, fluid effects, seismic responses, etc. will be required. Case histories will be extremely valuable, yet difficult to obtain. Increasingly, old geophysical (particularly seismic) papers that have been relied on for decades are being shown to contain flaws, invalid assumptions, etc., and must be scrutinized and publicized.

Rob Kendall

I'm not sure if any changes or additions are required. I believe most students probably have better/less biased access to things like microseismic and multicomponent technology.

Shawn Maxwell

I think we need to look at more cross-training between engineers and G&G. Also, I feel that learning the fundamentals of geomechanics is important.

Tom Sneddon

Sooner or later there will be a need for a 5th year of undergraduate study. More advanced mathematics, physics and geology are essential to developing a pool of well-equipped young people entering the profession who can move confidently into new lines of exploration and enquiry. I foresee the additional year would be inserted between the current second and third years to improve data handling, processing and mapping skills, before introducing two intensive years aimed at creating interpretation.

Ron Larson

None.

Glenn Malcolm

The geophysical curriculum needs to be better integrated between geology, reservoir engineering and geophysics as this is the reality in industry today and in the future.

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Bill Goodway

An expansion into more detailed seismic wave propagation and processing theory, as well as the addition of passive microseismic monitoring methods to better prepare geophysics students for entry into the Western Canadian industry.

Ken Mitchell

A fundamental physical science curriculum offers a robust understanding that affords current and future geophysicists the necessary tools to apply knowledge and notably to innovate. Attempts to specialize B.Sc. candidates as energy or mining industry technicians are not desirable. Geophysicists are best prepared for unknown future developments in theory and application of the science if they can solve problems from a core understanding of first principles.

A core curriculum should include consideration of the following, at the very least:

- Basic studies in geology (sedimentary, igneous and metamorphic). To include mineralogy, petrography and geologic processes. Grounding in structural geologic principles.
- Basic geologic field mapping.
- Basic applied mathematics that includes introduction and manipulation of Elastic Wave Equation, Hooke’ Law, Maxwell’s equations, Euler’s (many) equations, and similar building-block equations.
- Time series analysis...Fourier analysis, sampling theory, time and frequency domain manipulation. Seismic Time & Depth Migration theory and implementation.
- Exploration Methods (Potential Fields, Mining and Energy and Environmental applications). Well logging methods.
- Earthquake Seismology.
- Physics of the Earth, planets and solar system.
- Optics, Acoustics, Electricity and Magnetism, Newtonian Motion.

The studies listed above represent a nearly-full academic calendar with little room for further electives but the following are some possible suggestions:

- Effective Technical Writing.
- Basic Economic Principles.
- Computer Science and Programming.
What technologies should service companies be developing?

Penny Colton

They should develop integrated analysis tools / workflows that document improvements with each additional step, and provide QC of results / benefits of each additional processing application. I also think they should work on the integration of geological and production database type information.

Tooney Fink

The service companies currently do a great job at ‘keeping ahead of the curve’, but in the future I expect and want to see:

- Wireless field acquisition systems
- An optional alternative for dynamite sources (particularly where Vibroseis won’t ‘work’ because of access constraints) in the event that dynamite becomes socially unacceptable
- Continued leaps in seismic processing algorithms (like smart interpolators, noise/signal discriminators, better footprint removal, tough multiple removal, fast well-based inversion with probabilistic outputs)
- Interpretation tools that integrate all of the subsurface data digitally, and co-render many attributes
- Fast viewers that allow an interpreter to quickly evaluate hundreds of seismic attributes, yet are seamlessly connected to the big workstations
- Fast, full waveform forward modeling tools (dead easy desktop style)
- Interpretation workflows for microseismic that extract even more information from the microseismic event ‘attributes’
- Open hole (and maybe even cased hole or MWD) logging tools that give us the resolution, formation data and interpretations that we need to assess complex anisotropic reservoir rock

John Duhault

Service companies should continue to improve imaging technology (i.e. “Thinman”, AWAZ, SC/3D applications, etc.) and data integration technologies (i.e. “Transform”, etc.)

Kathleen Dorey

Service companies should be developing any technology that reduces the risk of exploration and development drilling. By reducing the risk of drilling in a cost effective and timely manner geophysical technology applications will continue to be sought after and in demand.

Neil Orr

New technologies I’d like to see service companies develop:

- Improved wireless acquisition systems for safer, lighter operations.
- Remote data QC capability.
- Data compression applications for segd and segy formats
- Interpretation systems allowing pre- and post-stack analysis (a few are available, most don’t take prestack data)
- More user friendly and intuitive interfaces for high end workstations and software would be helpful. It often takes years for existing technical improvements to be incorporated in day-to-day workflows within industry.

- Routine, accurate registration of S-wave data against P-wave data would result in this data being shot and used more frequently
- Software and workflows facilitating easy integration of 3D seismic, impedance, and attribute data into geomodels
- Cost efficient acquisition technology in environmentally / culturally sensitive areas
- Research into better acquisition methods in areas where S/N is an issue.
- Fundamentally improving signal to noise in processing.
- Effective multi-dimensional products suitable for enhanced attribute analysis.

David Cooper

- Interpolation
- Signal processing to remove source, receiver, and in particular, transmission effects
- Anisotropy effects in all forms and at all scales, as they affect seismic and other geophysical information processing
- Enhanced imaging through compensation for an increasing number of perturbing effects; characterizing these perturbing effects, then deliver summaries of these effects, in case they solve our technical goals.

Rob Kendall

I would like to see a better link between anisotropy and geomechanics (super specific but that’s where I’m at).

James Alison

Technologies that give an ever better description of the physical properties of the subsurface.

Tom Sneddon

Seismic has given us a great ride since the 1930’s and much remains to be learned about it. It isn’t the only method available to geoscience, though, and service companies should be looking hard at what other techniques can be developed and marketed to fill in the gaps conventional seismic can’t fill. Ground deformation measurement; electromagnetics; induced polarization and other known methods used in the mining business or in down-hole tools have never been fully exploited in the search for petroleum. The increasing need for higher levels of precision in depth to target determination and sensing changes to pore fluid chemistries should lead service companies into offering surface exploration tools based on electrical, radiation and electrochemical methods.

Ron Larson

For unconventional and tight reservoirs, service companies (as well as E&P company geophysicists) will be pushed towards a more engineering-centric deliverable. That is good. For years the geophysics community has cast envious glances at engineering budgets. We may soon be in integral part of that budget!

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Bill Goodway

I would like to see enhanced acquisition geophone/channel capability combined with new high-compute power processing algorithms to fully recover aliased noise and signal wavenumbers (beyond Nyquist) due to coarse 3D line spacings. This goal would enable a better separation and attenuation of contaminating high wavenumber noise from signal, and full wavefield reconstruction of signal by factors of up to 4 times the field Nyquist.

Ken Mitchell

I believe that microseismic technology is one area of focus with the potential for greatest advancement. While downhole microseismic is somewhat established, the wellbore-of-opportunity approach has serious limitations. Purpose-built observation wells can be prohibitively expensive and need precious lead-time to prepare. Surface recording of microseismic events could certainly be more robust. Service providers could expand existing markets by delivering cost-effective, timely solutions that yield reliable microseismic data recording, processing and interpretations of event positioning.

From the micro- to the macro-, I am also excited about the possibility of looking at the big picture of target basins. Even low-tech 3D data, when interpreted on a large, regional scale provides insight that supports good E&P strategy. Alternative methods that employ derivatives and gradients of HRAM data also have merit. Shale gas plays may be particularly impacted where such methods indicate regional shear stress within the sedimentary sequence.

Further, while the mining industry continues to pursue the holy grail of sub-1 Eötvös precision for gravity gradiometry recording, petroleum E&P operators may be unwitting beneficiaries. Surely the diamond miners will monopolize the first high resolution gravity gradiometry production systems. If E&P companies choose to access this technology, they may discover that there are important regional trends apparent from an entirely different and independent perspective. Considering that this type of data might be quite efficiently acquired from the air, there is some room for future advancements.

Considering the above, the commercial development and deployment of tools to integrate and manage more data of independent source will certainly aid geophysicists and their teammates into the future.