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Value of Integrated Geophysics

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This column, coordinated by the VIG Committee, is oriented towards the demonstration, promotion, or encouragement of the value of integrated geophysics. This may include short technical notes, business cases, workflow examples, or even essays. The format of the column is purposefully open, relaxed, and flexible to allow a wide variety of discussion without unnecessary burden. The column will generally be written by persons on the VIG committees, however, all members of the CSEG are invited to submit a short value oriented article to the VIG committee through committee chair George Fairs (GFairs@Divestco.com). Additionally, the VIG committee invites your letters. If you have a story, question, or comment about the value of geophysics, please send it on to George Fairs. We hope that the letters and columns that we publish are unique and different: tied together only by an interest in encouraging the value in our science and profession.

From Prospecting To Reserve Audits

Within the oil and gas industry, geophysics has been a science deployed by companies to reduce drill risk and increase the chance of success. Whereas gravity, magnetic and other forms of remote sensing data all have their role to add value in the search for hydrocarbons, seismic data has proven itself over the decades as the principle risk mitigation technology. Seismic data can be used in an exploratory, exploitation or development mode to delineate and characterize a resource or a reserve. With today's commercial technology, unconventional resource plays offer considerable additional production and reserves not conceived to be possible, let alone economic, as recently as a decade ago. Within North America, industry has been enticed once again by an opportunity that mitigates the risk associated with the presence or occurrence of the resource, shying away from true exploration where this risk is still prevalent. For resource plays, economic viability is measured by cost effectively extracting the resource, not in its prediction of occurrence; hence exploration by industry has been reduced to minimal activity levels in terms of seismic crew counts, the amount of data being processed and the amount of data bought and sold through the brokerage industry. Coupled with recent success by the United States to increase gas production domestically, the market for natural gas from Canada has been depressed. With the recent focus upon the development of unconventional resource plays within the Western Canadian Sedimentary Basin (WCSB) and the lack of exploration for new gas reserves due to various market factors, the amount of geophysical activity in Canada is currently quite low.

Recent geophysical activity has focused upon higher orders of application of the seismic method, using seismic attributes that are highly calibrated to rock properties, to describe reservoirs with greater clarity and detail. Yet, investments in the seismic technique appear to be a tough sell to management who want to cut

costs to maximize a rate of return from tight reservoirs with already challenged economic metrics. Unconventional resources have become a "mining style" operation in which the value of geophysics and seismic interpretations can at times be thought to be a further upfront capital expenditure with long cycle times for contribution. It's time to change the view that seismic applications in unconventional or conventional resource plays are often perceived as an expense item that increases upfront capital costs. The value and expense of seismic data is seldom reviewed in the context of full cycle project economics, let alone assessing the potential impact of a P10, P50 or P90 outcome on a per well basis. Using seismic data to develop a reservoir should be thought of in terms of an investment, not as an expenditure or liability. A dry hole is an expense that may have been avoided with the inclusion of geophysics.

From a reserves audit perspective, the value of geophysics and seismic data can be deemed a "reliable technology" when calibrated with geological and engineering data. This can have considerable impact not only by increasing the chance of success and improving drill outcomes but also impacting the booking of a reserve, the greatest impact most likely being the booking of a probable or possible reserve.

Background: Recent Initiatives

In December of 2011, the Calgary Chief Geophysicists Forum (CGF) Reserves sub-committee delivered a document to the Calgary chapter of the SPEE as consideration for an update to the Canadian Oil and Gas Evaluation Handbook (COGEH). The document is entitled, "Geophysical Applications – Using Geophysics for Hydrocarbon Reserves and Resources Classification and Assessment". The document was tailored after Chapter 3 (Seismic Applications) of the SEG Oil and Gas Reserves Committee (ORGC) which was included in the guidelines document created by the Petroleum Resource Management System (PRMS). PRMS consists of five (5) joint sponsors; the Society of Petroleum Engineers (SPE), the Society of Exploration Geophysicists (SEG), the American Association of Petroleum Geologists (AAPG), the Society of Petroleum Evaluation Engineers (SPEE) and the World Petroleum Council (WPC). The CGF Reserves sub-committee document was endorsed by the membership of the CGF and the CSEG 2011/2012 Executive. For a review of the complete CGF reserves document please go to the CGF website at: http://cseg.ca/members/chief-geophysicists-forum. The document was submitted for consideration for the next COGEH update. This document has been reviewed by the SEG OGRC, the SPE OGRC, the SPEE, WPC and the United Nations International Framework Classification for Reserves committee. The SEG OGRC thought the topic of using geophysics for reserves and resources was so important that there was a special edition of The Leading Edge Magazine in September of 2012, entirely focused upon this topic which includes articles from Canadian assets. Numerous technical examples are discussed in this edition of the publication, showcasing how geophysics can add value.

The CGF Reserves Sub-committee document sites several case studies to demonstrate how geophysics and the seismic method were used to image, delineate, describe, and characterize a resource or a reserve. Different seismic attribute parameters calibrated to known rock properties in order to describe a resource or a reserve, often results in considerable enhanced prediction accuracy. Such accuracy, when supported by drill outcomes, permits seismic data to be used as a reliable technology for reserve description. In 2008, the SEC defined reliable technology. A "reliable technology" permits the use of technology (including computational methods) that has been field tested and has demonstrated consistency and repeatability in the formation being evaluated or in an analogous formation. This new standard will permit the use of a new technology or a combination of technologies once a company can establish and document the reliability of that technology or combination of technologies. Focusing upon the meaning of a reliable technology, seismic data, when calibrated to this extent, can be used in the reserve audit process with significant impact and added value. This can provide a higher degree of confidence associated with a reserve booking. Assuming hypothetically that a company has drilled out 5 AVO anomalies and current mapping suggests 5 more look-a-likes, seismic

data can be used as a reliable technology then to describe a probable reserve that is associated with the 5 currently undrilled anomalies.

Discussion: Value Creation While Prospecting

Repeatedly, geophysics and seismic data in an exploration, exploitation or development mode have been proven to mitigate drill risk, enhance well deliverability and impact reserves and resources bookings. However, not every play is conducive to the conventional seismic method as some reservoirs may be too thin to adequately resolve the geologic formations with seismic wavelets. Recent advances in high density, high frequency seismic data such as in oil sands plays see this resolution increase for thin bedded formations. Additionally, some plays may not be able to support the capital investment of seismic data. For instance 3D seismic for a shallow gas play, while it may offer great insights, economics will not support the cost of such a highly sampled 3D for low deliverability rates for a commodity currently with a low market price. Even plays with considerable well control can benefit from the inclusion of the seismic method if well deliverability outcomes vary considerably. However, some plays may not require the seismic method to achieve a threshold of acceptable economic value addition. The question remains however, how much additional value could be achieved with the inclusion of the seismic method?

During the execution of a Plan of Development (POD) for a given field or reservoir, seismic data can often image, characterize and describe the reservoir prior to drilling, to predict regions prone to enhanced deliverability. Enhanced deliverability directly impacts the rate of return on capital invested. It is reflected in the description of a P10, P50 or P90 outcome. Hence, geophysics and seismic data are often used as the "seeing eye dog" to depict what is happening in the sub-surface to enhance drill outcomes.

Seismic data can provide considerable value in the development of unconventional resource plays. Structurally, seismic data can help to geo-steer horizontal wells and can be used to plan the development of a resource to provide better production outcomes. Seismic attributes that are highly calibrated to known geology, can provide considerable risk mitigation in the development of unconventional resources. Whether it is with the use of semblance to find faults within the reservoir, curvature volumes to identify the orientation of local stress fields, Poisson's Ratio to describe subtle changes in lithology, Mhu-Rho to describe variances in matrix lithology or Vp-Vclay volumes to find a carbonate edge, all such attributes (and others) can be used to mitigate risk by characterizing the reservoir with greater confidence. Diagnosing what attribute to use when for a given play is critical to this exercise. The process of diagnosis is often conducted in the realm of petrophysics, where rock properties are studied in detail using logs, core and laboratory measurements. Calibrating these rock properties to seismic data is critical to the success of seismic data reliability.

An interesting quote came out of a 2009 SEG convention abstract entitled, The Value of Geophysics in the History of Production at Bay Marchand Field. The opening paragraph really hits the nail on the head.

> *"Geophysics has helped Chevron produce the most oil and gas from any of its fields in the Gulf of Mexico – Bay Marchand. From 1938 until today, geophysics has had a measurable impact during discovery, delineation, development, production and revitalization of the geologically complex field. During this time, as geophysical technology has become available it has been applied with largely successful results."*

Discussion: Value Assessment for Reserve Audits

Just as seismic data is used to mitigate drilling risk for value creation whether it be for a conventional or unconventional reservoir, it can be used to enhance the confidence of booking a reserve. Through the National Instrument NI 51-101, public oil and gas companies report their reserves on an annual basis.

Through this process, companies wish to have their efforts and achievements recognized as having added value to the organization. Assessing the value of a corporation's reserves has a material impact upon a corporation for attracting investors and return on shareholder investment. These reserve numbers are then used to estimate net asset value. The company discloses this information as it is used in part by the capital markets and the public to make investment decisions. The quality and extent of the technical work performed can add confidence to a reserve auditor. In the past, the contribution of geophysics through the use of seismic data has had limited impact, often just defining the areal extent of the reserve for volumetric analysis. Technological developments during the past couple of decades suggest that it is possible for seismic data to be used to predict reservoir properties through reservoir characterization. These predictions, if well calibrated with a high degree of confidence, can be deemed a reliable technological application that may in turn have considerable impact on the booking of a reserve. An example of this would be using seismically derived attributes (such as LMR derived rock properties) to demonstrate that a play fairway extends over a larger area of company land, that a sweet spot with encouraging well results can be reliably mapped and have additional reserves booked to it, or that a prospective play has the appropriate rock properties for unconventional development. The most likely categories to benefit from the inclusion of the seismic derived story will be the probable and possible reserves, not to mention resource potential, however, over-booking of reserves is possible if the pinnacle reef or channel sand is assumed to cover all of the spacing unit being booked. Without seismic, reserves bookings are based solely on well results which are not always indicative of a play's future potential, as completions are optimized and the resource is further delineated with time. The message being that reserves can be realized sooner and with greater accuracy when seismic methods are utilized.

Proved reserves represent the hydrocarbon volume in place that can be estimated with reasonable certainty to be commercially recoverable from a known reservoir under existing economic conditions, operating methods and current government regulations. Proven reserves are reported under two categories, namely proven producing and proven non-producing with a likelihood of recovery being ninety (90) percent. These are often referred to as "1P" reserves. Probable reserves represent the volume of hydrocarbon in place that is equally likely that the actual remaining quantities recovered will be greater or less than the sum of the estimated proved plus probable reserves. Hence a fifty (50) percent confidence factor is applied to this category. The combined proven plus probable reserves are often referred to as "2P" reserves. Companies are often valued on their 2P reserves. Possible reserves represent the hydrocarbon volume in place that is less likely to be recovered than probable reserves. Under a probabilistic approach, the likelihood of recovery is better than ten (10) percent. Combined proven plus probable plus possible reserves are referred to as the "3P" case. All reserve auditors are guided by the same rules as outlined in the Canadian Oil and Gas Evaluation Handbook (COGEH). All reserve audit companies consider parameters such as pressure, porosity, permeability, production technique and methodology, future capital requirements, production economics and the economic viability of the reserves.

The greatest value comes from not just using the seismic data more fully to characterize the reservoir but integrating it with the geology and reservoir engineering technical efforts to provide a fully integrated tri-disciplinary geologic model of the reservoir. One excerpt from the Petroleum Engineering Handbook (PEH) includes;

> *"Rather than being limited to assisting in the identification and delineation of prospects, geophysics is now increasingly being used for the characterization of the internal geometry and quality of reservoirs themselves and is often used as a means of monitoring reservoir changes between wells during production".*

The Challenge

So if geophysics and the integration of seismic data add value to the exploration and development of conventional and unconventional resource plays, why is there not more geophysical activity in the Calgary marketplace? Why are activity levels and seismic crew counts so low? Why is it that geophysical data and its relationship in reserves and resources classification and estimation not more widely published? The United States production levels have had a huge influence upon our Canadian market prices. Their recent domestic success with tight unconventional reservoirs is leaving Canada with an over-supply of natural gas, resulting in depressed natural gas prices. Without an outlet to get natural gas off of the North American continent, we are left to developing internally an expanded requirement for natural gas consumption, to improve commodity prices. Hence considerable Canadian industry focus is upon the construction of Liquefied Natural Gas (LNG) ports and facilities on our West Coast and the approval and construction of additional pipeline capacity to get the product there. It will take several years till natural gas moves to the coast and out to world markets but we need to get this accomplished. Our saving grace for activity levels will be that current gas producing wells are experiencing production declines and the current amount of new drilling is not what it has been in the past. This will cause an equalization of supply and demand in the future. As LNG facilities and new pipelines receive regulatory approval, so the natural gas industry will increase activity levels once again. After all, natural gas is still one of the world's cleanest fuels.

In the interim, geophysics and the use of seismic data for unconventional resource plays seems to be applicable but there still seems to be resistance. Why is there not more of this type of reservoir characterization work using highly calibrated seismic attributes? The answer may reside in the cost cutting approach used to develop unconventional resources. Seismic data is perceived as an expense that does not have a guaranteed outcome or impact. While this can be assessed in stages using 2D data, 3D data, and forward models derived from well-logs and the like, full scale inclusion does not seem to be occurring ubiquitously. The financial markets appear to hold public companies on a tight fiscal leash on a quarterly basis. Investing in seismic data with the turn-around cycle time required for a high end attribute volume interpretation cannot be measured on a quarterly basis. Instead, the contribution of geophysics must be considered on a project basis. Coupled with the fact that our north country has to deal with seasonal access to the potential resource and exploration cycle times are now measured in years, not weeks or months as the winds of Bay Street would prefer. Regrettably, geophysics becomes part of the upfront capital expense but not making use of this technology can result in less value to be created than could have been produced. Geophysics and in particular the seismic method can be used successfully and economically to add appreciable quantifiable economic value to a project (Hunt, 2013).

The Conundrum: The Seismic Analogy and Studying For That Final Exam

Most university students, wanting to get the best mark possible for a course, will take the time and effort to study for the final exam. Studying does not come with a guarantee that a higher grade will be achieved, but most students perceive the value associated with the exercise. Studying may make the difference between achieving a D-grade or an A+. Studying does not guarantee an A+ outcome, just the chance or opportunity of better success.

The drilling of wells is often described in industry terms as a P10, P50 or P90 outcome. Drilling better producing wells increases deliverability and enhances economic value. Hence, seismic data must be perceived to be a value adding tool to increase the economic impact of a project. It needs to be perceived as an investment, not as an expenditure. It is true that we still have folks in industry that still believe they can prove up a prospect through the drill bit a lot cheaper than the cost associated with acquiring seismic or other geophysical data. Are they optimizing their drilling success? Are their economic rates of return better than the competition? Geophysics can often be perceived as a financial short cut that can be taken to cut costs.

Historically, people developed a play concept geologically, investigated the applicability of seismic data to mitigate risk, acquired some seismic data, interpreted it, bought the land and drilled a well. Today, it seems people buy the land, drill the well and then ask the geo-sciences what went wrong! Historically, companies set their seismic budgets at 15-20% of their gross exploration / development budget. This is not the case today, the numbers are half of that. Seismic expenditures are perceived to be an expense which can be tossed aside as it comes with no guarantee. Drilling a well gives one the opportunity to reap the flow of hydrocarbons. It seems not to matter whether the well could have been optimized geographically to achieve a better result for the monies invested. How much value has not been recognized because less than optimal wells were drilled? Are we reluctant geophysicists that aren't willing to show the value that our profession can add within our company or within our cross-discipline industry? How else can we show the innovations within our integrated science that improve our companies' bottom line?

If we don't study for the figurative exam, how else do we expect to achieve the results we need? Canada needs us to blaze that trail!

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