Overview of VIG Columns in RECORDER: May 2013 – March 2014

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As part of the VIG (Value of Integrated Geophysics) initiative, a series of articles and columns were published in the RECORDER from May 2013 until May 2014 inclusive. The purpose was to advance the use of geophysics for business purposes by educating and inspiring our readership. The articles and columns were focused upon the value of geophysics; how to calculate it, how to find it, how to communicate it and perhaps the risks of ignoring it. The following is a short summary of the articles, mostly in the words of the authors. Should any of the summaries below inspire one to further investigation the full articles and columns can be found on the CSEG RECORDER editions webpage located at http://csegrecorder.com/editions.

The May 2013 RECORDER issue contained Estimating the value of Geophysics: decision analysis by Lee Hunt. This article discussed and clearly showed how to calculate the value of seismic data even in an environment rife with imperfect information. It generated a great deal of feedback and encouraged a few geophysicists to use the mythology to calculate value for their own projects. The strong feedback from this column was a significant impetus to the decision to run a monthly column and therefore, to this issue as well.

The article reintroduced the concept of decision analysis (Newendorp, 1975), which is the formal science of decision making and applied it to a resource play example. Decision analysis is a logical and objective method of estimating the expected net present value of choices or decisions that might be made in business. The method uses a tree-like structure as below in Figure 1, and considers the probability of various outcomes as it follows the series of successive choices that may be made. In Hunt 2013a, a fairly simple decision to use or not use seismic produces a fairly detailed or complicated looking decision tree.

Figure 1. Adapted from the VIG Doodletrain course. A simplified cartoon of a decision tree.

Figure 2. Adapted from Hunt 2013a. A chart of expected values as a function of the reliability of the seismic interpretation.

The method that Newendorp (1975) and Hunt (2013a) suggested considers seismic as an imperfect kind of information, and uses Bayes’ Theorem to modify the seismic accuracy by some ultimate prior knowledge. The use of prior knowledge is ubiquitous in inverse theory, and it takes on a key role in decision analysis for modern resource plays in that it suggests that a more realistic solution will be arrived through integration. How does the use of Bayes’ theorem suggest integration? The suggestion is made in this way: the ultimate probabilities represent the expected distribution of outcomes from geologic or engineering data. We thus damp or modify our prediction confidence based on this important knowledge that lies outside our specialty. Using other (geologic and engineering) knowledge is a crucial way for us to do our work better as geophysicists, and as such, doing so appropriately can be a source of some controversy.

While Bayes’ theorem is an important mathematical motivation for integration that we should be aware of, we geophysicists have an even more direct responsibility to consider, and that is the reliability of our seismic predictions. Reliability, or accuracy, of seismic is the thing that we are most directly responsible for. The VIG Doodletrain course emphasizes this point repeatedly, and for good reason. If we are to affect the value of our business, and thus be valuable ourselves, we must manage our geophysical work so that it is as accurate as possible to the business decision at hand. Figure 2 demonstrates how the expected value increases with increasing seismic reliability. Note how there is a reliability below which the use of seismic actually has a negative impact on the economics. There is another article by Hunt in this VIG Special Edition that discusses seismic reliability in further detail.
The next issue of the RECORDER column was September 2013 and was also written by Lee Hunt and was entitled The importance of making conclusions, and frameworks in reasoning.

The column was a kind of confession about the inadequacies of geophysics in answering questions about the earth and of business in a direct and accurate way. Hunt suggested that applied geophysicists labor under such a pervasive set of imperfections and incongruencies that we must all be affected to some degree by cognitive dissonance. Whether that was meant to be a humorous comment or not, he moved then to argue that the best way to manage this imperfect situation, this imperfect application of science, is indeed to accept the situation and find ways to both communicate our state of uncertainty and at the same time to work to improve upon it. The need to make a conclusion, give advice, produce maps and predictions cannot be denied if geophysics is to be of use. If this is so, we need to be realistic about what we are doing geophysically and how we are doing it.

The frameworks in reasoning part of the article was presented as a way of managing and partially mitigating the weaknesses in our application of geophysics. Critical thinking was briefly introduced, and in particular, the notion of inductive reasoning. Inductive reasoning is the critical thinking school’s parlance for the scientific method, and as such is very relevant to what we do in industry. In inductive thinking, we do not speak about the certainty of a conclusion: we may only speak of the conclusion’s probability. Hughes et al (2010) describes inductive confirmation as the following:

\[
\text{If } h \text{ then } o.
\]

\[
o.
\]

\[
\text{It is probable, therefore, that } h.
\]

Where \(h\) stands for the hypothesis, \(o\) stands for the observation statement that is logically deductible from \(h\).

Even if we geophysicists can only make probabilistic conclusions (or estimates) we can still try to make our estimates as likely, or as in Hunt 2013a, reliable, as possible. We can draw further from critical thinking methods to justify ways to improve the reliability of our conclusions. One of the methods we can use to advantage is that of forming complex arguments. A complex argument uses several forms of independent evidence to support the conclusion. In general, the more independent supporting evidence that can be brought to bear on a problem, the more likely that conclusion is to be true. An example of this, from Hunt 2013b, is shown in Figure 3. In this example, A V-argument is used to support an assessment of fracture density. The key concepts of this V-argument are the following:

1. That the evidence types are truly independent. Each of the methods in Figure 3 considers a different element of physical observation or causal relationship to fracturing. If we had simply looked at different measures of AVAz or different kinds of curvature, this would not be true.

2. That we might still have fracturing even if one of the types of evidence had a negative indication.

\[\text{AVA}_{z} \quad VVA_{z} \quad \text{Curvature} \quad \text{Young's Modulus} \quad \text{Diffraction Imaging} \]

\[\text{Fractures} \]

\[\text{If } h \text{ then } o.
\]

\[o.
\]

\[\text{It is probable, therefore, that } h.
\]

Where \(h\) stands for the hypothesis, \(o\) stands for the observation statement that is logically deductible from \(h\).

In our business, we are ultimately concerned with the productivity of well locations. Complex arguments are typically required to fully consider well productivity. In a complex argument, several sub-arguments are used to support the overall conclusion. Figure 4, from Hunt 2013b, illustrates a complex argument concerning well productivity. This illustration shows how the amount of work in processing and interpretation might become quite large in order to comprehensively address productivity for some wells. Of interest is the ubiquitous need for elastic information to address the sub-arguments pertaining to productivity.

In the October 2013 column Kurt Wikel discussed the future relationship of geophysics and geomechanics in The Future of Geomechanics and What It Means for Geophysics.

The key to geomechanics and 3D geomechanical modeling in the future will be integration of seismically and microseismically derived estimates of rock mechanical properties such as Young's Modulus and...
Poisson’s Ratio. Also, we need estimates of horizontal stresses (Figure 5) and how those attributes change in the time lapse domain. In much the same way that seismically derived time lapse attributes have aided the calibration and building of reservoir models offshore, seismically derived rock properties and estimates of stress coupled and calibrated with a 3D geomechanical model are the next step toward better completions, reservoir modeling, and reservoir monitoring onshore.

We have only begun to tap unconventional resources, and future EOR and recompletion opportunities are many. The future for geophysics is quite bright in this sense, both as a predictor and a monitoring tool for upcoming development. For our part, geophysicists need to take an active role in demonstrating the ability of seismic to estimate, delineate, and monitor quantitative data valuable to engineers through time. Through this approach, the interaction between engineers and geophysicists will hopefully become more of a two way street.

![Figure 5. Arbitrary line through an isotropic closure stress volume, derived from seismic data, and horizontal wells from a single pad in 3D space. In simplistic terms the cool colours are relatively easier to fracture than the hot colours. From Monk et al, 2011.](image)

In the November 2013 issue David Gray discussed the role of geophysics and statistics in Unconventional / Resource plays in An Unconventional View of Geophysics. Shale plays have been described as statistical plays. The implication being that, on average, wells will be economically viable. Historically, statistics was developed to help gentlemen gamblers beat the odds; that is, do better than the average. The fundamentals of seismic, Hooke’s Law, shows seismic is the relationship between stress and strain. Very slight modifications to tools that are already developed, like AVAZ and LMR, allow for the estimation of all the principal stresses prior to drilling production wells in shales. Using the stresses in an intelligent way, the odds of drilling and completing economic wells are increased. When we use the seismic data in this way to improve our odds of successful shale wells, then we are truly treating shales as statistical plays in the true historical sense.

The December 2013 issue contained the last VIG article written by Lee Hunt, which was entitled Many correlation coefficients, null hypotheses, and high value (Hunt 2013c). The intent of this short work was to discuss elements of statistical methods and illustrate their relevancy to industrial geophysics. This column was a necessary act of “tying” together the previous two VIG columns from Hunt. The other articles both discussed probability and reliability of geophysical outcomes as essential concerns of a value oriented earth scientist. This means that geophysicists need to have some working knowledge of statistics and probability to do their jobs. Of note in the article was the concept of sample statistics versus population parameters. Samples and populations are worth thinking about as we often miss-apply our work by not considering that a change of population may have occurred. This is especially important in resource plays, where a change in population may mean the permeability, fluid, or brittleness distributions, or the pressure or fracability, may have suddenly changed and expected producability of the wells may have also changed.

Other items of note in the column are the concepts of the null hypothesis, tests for statistical significance, and correlation coefficients. Hunt also points to literature that expounds upon the many interpretations of the correlation coefficient. Of final note, Hunt shows that in a multi-variate system, important and significant variables may fail tests for statistical significance unless they are tested in a multi-variate manner rather than simply testing each variable separately. This concept can be relevant in a great many of the things that geophysicists attempt to predict, including producability, fracability, and permeability, all of which are multi-variate problems. This idea also refers back to the previous two columns by Hunt, where reliability is shown to be important, and where complex arguments are used.

The January 2014 VIG column was a cautionary of the risks of operating with geophysical information. An example of measurable value from a 3D seismic survey by Charles Welsh presented an example from the commonly exploited fluvial reservoir containing Heavy Oil in the East Central part of Alberta.

The area is heavily drilled to less than LSD spacing (less than 400 m intra well spacing) yet errors in just the use of Geological mapping can still lead to drilling ‘DRY’ and therefore uneconomic outcomes.

This article shows the benefits and cost advantages of spending capital on ensuring that risk is reduced significantly. This risk reduction after a significant capital spending on seismic data still would give or lead to a better allocation of funds that are available within the petroleum industry.

In summary I would like to say that we should approach the exploitation of our hydrocarbon resources with a full holistic approach. Consider the quality of the acquisition parameters, the processing methods and the integration of all other pertinent data before we make the economic decision. Value is more than reducing capital,
consulting, and labour costs: we have to think in terms of how better we can fully exploit a dwindling resource. Consideration of all aspects on the effect on society must be taken, as this in itself adds value.

The example illustrated in this column illustrated a clear economic advantage from the use of 3D seismic.

The article in the February 2014 issue was our first joint authorship. Marian Hanna and Doug Uffen discussed The Value of Geophysics: 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. From a reserves audit perspective, the value of geophysics and seismic data can be deemed a “reliable technology” when calibrated. 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.

As an analogy, most university students 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 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 is a value adding tool which increases the economic impact of a project. It needs to be perceived as an investment, not as an expenditure.

If we don’t study for the figurative exam, how else do we expect to achieve the results we need?

The March 2014 column was quite exciting for the VIG committee as it was our first and only column offered up by someone who was not part of the VIG steering or resource committees. Ms. Jan Dewar was kind enough to provide us with When Geophysics is a Second Language, a dissertation on the importance of communicating appropriately with other professionals.

This brief article was a call to geophysicists to invest thought and effort into how we present our technical results to professional colleagues who do not ‘speak’ geophysics as their first language. Without effective communication, we will likely be tuned out or dismissed, with costly business decisions the result. To ensure that the full value of our technical work can be realized, remember the importance of communicating clearly.

Use words and pictures that are meaningful to your audience
Not too many

Figure 6. (From Jan Dewar – March 2014): Accept that not everyone will appreciate equations. Find alternate ways to explain their meanings.

The article offered some additional specific suggestions on how to structure a presentation, and a checklist for clear communication.

The April 2014 column was our second joint authorship and the last column of a technical or instructive nature. Amy Fox and Carl Reine coauthored Shortcuts and Backseat Drivers: Trying to Integrate Geophysics and Geomechanics for Better Engineering.

The article tackled one of today’s major challenges associated with moving geomechanics from traditionally wellbore-based analyses to a full 3-D understanding through integration with geophysics. It was, in essence, a plea to get engineers, geophysicists AND geomechanics specialists speaking the same language and working together. Traditional geomechanics can answer many of operators’ important questions rigorously at the wellbore, while geophysics can answer those same questions where there isn’t well data, but only in a relative sense. The article posed the question of why, then, are the two disciplines not more integrated? To answer this, we looked at each discipline’s perception of the other. We also extensively explored the potential confusion, misunderstanding and frustration caused by each discipline using different terminology for common rock properties.

In an effort to illustrate the potential benefit in integration, the article used natural fracture prediction as an example of how geomechanics and geophysics can complement each other to create a more complete picture of reality. Geophysicists use seismic data to assess the expected fracture density in a potential well. However, due to the complexity of fracture mechanics, the only way to truly understand a fracture population is to measure it in situ, at depth, which we a geomechanics specialist does using wellbore image logs. The article asked the reader to consider how, if this geomechanical “ground-truthing” was actually performed more often, would it alter how we make our fracture predictions?

The final VIG column in May 2014 was by myself and was just a summary of what the VIG Committee had accomplished to date and what some our plans for the future were. As this is well covered elsewhere in the issue there is no value in revisiting it here, and the VIG is all about Value.

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One of the goals of the series of articles and columns that we have just summarized was to inspire our readership. Should any of the preceding summaries or their parent articles and columns inspire you gentle reader to respond with some writing of your own, the VIG Book is still an idea the committee is pursuing and we will be more than happy to consider for publication your perspectives on the pursuit of value focused geophysical methods and practices.

References
Hunt, L., 2013c, Many correlation coefficients, null hypotheses, and high value: CSEG RECORDER, 38, 10, 46-54.
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has been in and greatly enjoyed the geophysical service sector for over 30 years and during that time has chaired the 2000-2001 CSEG Master License Committee, sat on the 2002 APEGGA Practice Standard for Quality Inspection of Geophysical Data, sat on the 2013, 2014 and 2015 CSEG Symposium committees chaired the CSEG VIG committee from inception until the end of 2014 and now sits as a member at large. Since 2011 he has been an employee of Divestco where his responsibilities include developing and promoting speculative 3D seismic programs, brokerage of reflection and microseismic data and pretty much any other interesting and cool aspect of geophysics Divestco is involved in. He welcomes comments and queries at GFairs@divestco.com.