The need for an interpretation strategy

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This article analyzes some ideas about how the interpretation framework has changed in recent years and some requirements imposed by newly available technology to efficiently deal with geological uncertainties.

The need to establish an interpretation strategy before starting any interpretation and some of its components are considered. Some critical aspects of the interpretation environment are also reviewed.

The inspiration for this paper came from a great article in the February 2011 issue of *TLE*, "Interpretation in the year 2010—How far have we come?" in which Don Herron summarized the results of a workshop at SEG's 2010 Annual Meeting. This article deals with what an interpreter does every day rather than present a specific case study or describe a special interpretation technique applied over a particular prospect. Not many articles with this focus can be found in the literature.

Introduction

Imagine an exciting project ready to be assessed by a team composed of an engineer, a geologist, and a geophysicist.

Now imagine the manager explaining to his boss what the team is going to do over the next few months. Perhaps he is saying that the engineer is gathering the well-testing data, the geologist is reviewing the logs, and the geophysicist is looking at the seismic.

Sounds familiar, but this doesn't seem to be an integrated team approach as described in Herron's article; it's just three individuals working on the same project. In other words, this would be a "nonintegrated approach" that might underutilize the value of today's interpretation capabilities.

Nowadays, from the geological and geophysical (G&G) point of view, two basic issues are widely recognized in the oil business:

1) A prospect's promise or profitable oil field development will be fulfilled only if each component of the oil system works properly.
2) If the first point is established, success usually depends on what the G&G&E people do to identify new prospects or development opportunities.

As related to the second point, many changes have taken place in the way that geoscientists work and in the quality of their predictions before drilling an exploration or development well.

Factors responsible for those changes include an improved knowledge of oil systems and their components, and the development of new technologies that integrate well data and 3D seismic data (e.g., better attributes, and special processing), portfolio management, and risk analysis procedures.

In other words, at the point that some basic data are available for interpretation (e.g., 3D seismic, logs from existing wells, production data in the neighborhood or in an oil field, outcrop data, interpretation reports), the geoscientist needs a detailed plan or, even more important, the company needs a plan because trial and error is hardly ideal. Such planning is possible today. So why not plan?

This plan or interpretation strategy determines how the team is going to look for prospects or development locations and evaluate the reserves and risk.

Why do we need a plan? The reason is simple: nobody wants to construct a home without first seeing the architect's plan.

The key to a good plan is that the initial scenario contain plenty of uncertainties (just like the psychological process of thinking about the requirements to reach a desired goal on some scale).

To be successful, the strategy must be credible, apply the level of technological refinement required, and be scheduled in a way that allows to the oil company to deal with internal or external commitments.

Finally, the continuous evaluation and correction of the strategy during its execution and, more importantly, comparing results with the predictions, will determine the effectiveness of the strategy and the value of the acquired information.

So, today's G&G&E interpretation process has changed significantly from what it encompassed just a few years ago, although it still includes traditional interpretation work.

Defining the scope of the problem

Today's technology allows geocientists to propose several new types of predictions during the evaluation of a project. For instance, in addition to the traditional play prognosis, it is also possible to prepare some volumes of reservoir facies distribution, or to predict some anomalous pressure zone, or estimate the tridimensional distribution of a seal of a few feet, or quantify the volume of a natural fracture zone, etc.

These predictions can be done through attribute and special processing volumes (SPV) and generation of many different data types, in some cases using only seismic data as input and in some others adding well data.

In this article, a distinction will be made between attributes and SPV.

The term "attributes" could be defined as the result of a mathematical operation on the seismic data without including any other data. Thus, the attribute resolution remains in the seismic domain (e.g., coherence or curvature volumes).

SPV involves seismic data and data from wells (e.g., logs, production, lithology) and therefore SPV resolution differs from seismic because other data impact the output. Consequently, such resolution could be higher than the seismic resolution—for instance, when a pseudogamma-ray volume is generated by using seismic and GR logs. Acoustic impedance is the most typical SPV.

Very often, some attributes contribute input to SPV

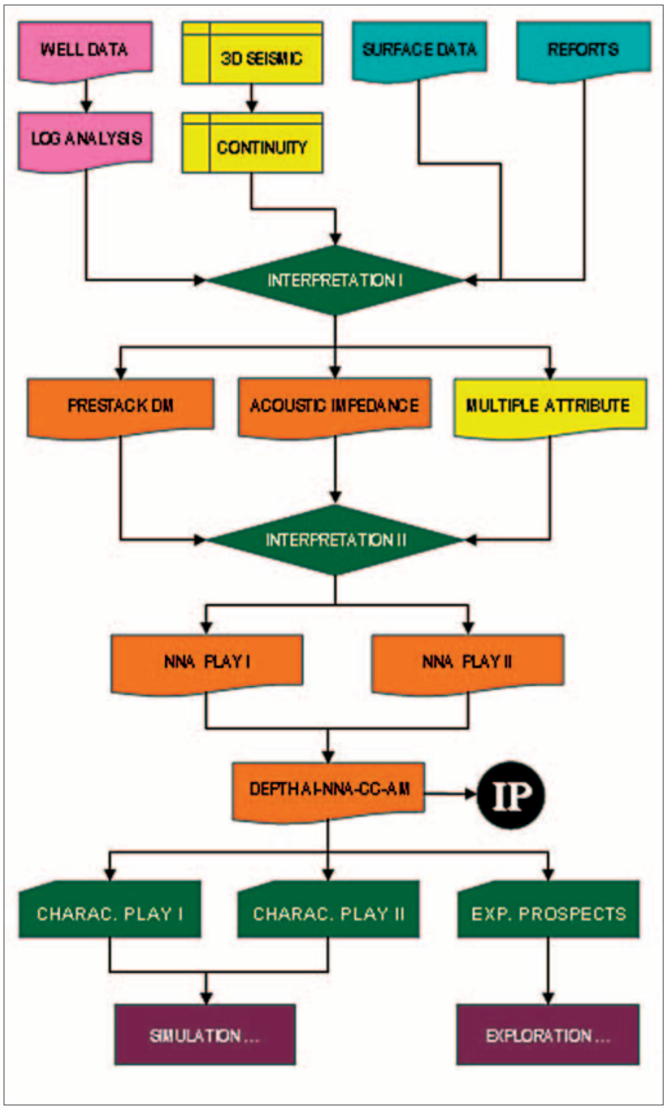

Figure 1. *Example of an interpretation workflow to predetermine problems to be addressed and their proposed technical solutions. Yellow = 3D seismic data. Pink = well data. Cyan = surface geologic data, old reports from previous G&G interpretation, and related information about the oil system. Green = interpretation stages. Orange = SPV. IP = interactive process or update when new well information is added.*

generation through a neural network process. There can also be a mathematical operation between two SPVs or an attribute and an SPV that clarifies some prospect uncertainty.

However, the availability of SPV plus the traditional geologic and geophysical knowledge require that the geoscientist substantially increase the size and number of data sets in the evaluation of a prospect.

The problems caused by this new environment include:

1) The need to define, early in the process, the main components of the oil system to be analyzed or the uncertainties of the project.
2) Prioritizing, because of the many initial pieces of information and the data volumes to be generated, what is primarily and secondarily important.
3) The challenge of putting everything together in a practical workflow (including implementing the major technological solutions and state-of-the-art interpretation) that quantifies the defined uncertainties in an acceptable time schedule at a reasonable cost.

If those three points are adequately addressed, most components of an interpretation strategy are installed and the team will be able to see, after some time, the best route to its goals.

The role of the interpreter today is strongly related to his or her skills in solving those problems in a sophisticated way rather than being an expert in the generation of some particular attribute or application.

Components of an interpretation strategy

Assuming that all basic data are available along with an appropriate seismic volume (i.e., reflectivity model) and wells/seismic solidly tied, (in some projects, outcrop data or other additional types of information are a must), the initial step is to set up the interpretation strategy, with full G&G&E participation, by considering the following:

- Geologic uncertainties to be analyzed (potential for four-way closures or fault-bounded closures, stratigraphic traps or fault bend folds, natural fractures or permeable sands, shale gas or tight oil, etc.). In other words, answering the question, "What are we looking for?"
- Available basic data (modern or old logs, many or few wells, well testing, poor or missing mudlogging reports, etc.). Every project has many different data types which makes each project a unique puzzle. Maximizing the use of each set of data is an important part of the plan and it is advisable to think about it in advance.
- Appropriate technology to resolve the geologic uncertainties (e.g., if the priority is to delineate stratigraphic units, poststack acoustic impedance would be appropriate).

Another early step involves determining the data models (using as input the seismic reflectivity model) to be generated.

An arbitrary classification of commonly available models includes:

- Layer models: Any type of acoustic impedance product.
- Continuity models: Volumes generated to highlight the lack of continuity of a geological unit (coherence, semblance, similarity, etc., or any combination).
- Fluid models: Algorithms able to distinguish fluid presence (e.g., direct hydrocarbon indicators). AVO products in general (gradient, slope, poisson, LMR, etc.) fall in this category. Simultaneous inversion is an enhanced case because it is a fluid model that includes a layer model.
- Frequency models: Mostly represented by the different modes of spectral decomposition. The attempt to isolate single geological events can be attempted with param-

eters and sequence variations over many different data sets as happens when angle or offset stacks are tested to find the best geological event isolation.

- Facies models: The classification or clustering volumes (e.g., like K-means, PCA, unsupervised vector quantization, and self organizing maps) to reduce and classify poorly evident geological features.
- Properties models: Pseudovolumes (qualitative or quantitative) created from seismic data and some specific well data type through the use of a neural network. Examples are pseudolithology, pseudo-GR, pseudo PHIE, etc.
- Probabilistic models: Similar to properties models but outputting volumes that predict the probability of sands or other geological features.
- Depth models: The overall output of any depth-imaging volume.
- Pressure models: Volumes predicting the stress, fracture gradient, etc. of a particular abnormal pressured layer.
- Synthetic models: Volumes related to synthetic data and derivations, from 1D, 2D, or 3D synthetic data sets. An example is forward modeling to understand a particular reflectivity response from the actual seismic data by simulating a synthetic response.

The workflow or dynamic structure of the job determines the precise order in which tasks are going to be done. The goal is to keep the interpreter from having to continuously improvise. For instance, it is obvious that the conversion to a depth volume of some useful attribute must be done after generating the attribute and extracting a time-depth relationship from the PSDM volume.

Putting all the steps in order helps to visualize possible obstacles, optimize the timing, and avoid dead ends.

This requires a considerable effort from interpreters in a short time but the result is well worth it. This thinking process is essential to the creation and refinement of a plan, or integrating it with other plans; that is, it combines forecasting developments with the preparation of scenarios of how to react to them.

The following workflow will be used for descriptive purposes.

Prior to starting the analysis, it is necessary to establish some criteria.

It is difficult to generalize this function because each project has different uncertainties and geological concepts so it is obvious that a specific project requires a specific interpretation strategy, designed to accommodate the status of the project and its characteristics.

Consequently, there is no valid overall strategy, even though several projects may share several common features. We have found, even in the same block of a basin, remarkable differences between projects.

Thrust faulting areas, carbonate platforms, naturally fractured rock zones, fluvial sands in a gentle structure, unconventional reservoirs, etc. are in several play types that would require significant changes in our workflow.

Sometimes the seismic data are a key issue, but in another play type, a geochemical study or detailed well-log correlation may be the key to characterize the trap.

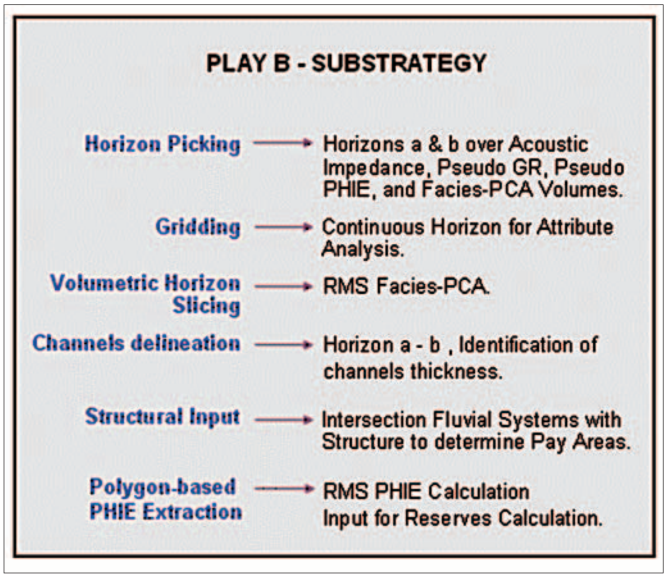

Figure 2. *Example of a substrategy showing the planned tasks to analyze some fluvial channels.*

Proposed technical solutions in the workflow must be helpful in understanding trap mechanism, seals, reservoir rock, timing, charge, oil migration, etc.

Figure 1 shows an actual workflow for an interpretation strategy for a project that had two mature productive units and several uncertainties. This workflow can be divided into three cycles, each ending in a G&G interpretation (picking horizons and faults) stage (green).

The first cycle (up to Interpretation I) includes input data (well data, 3D seismic data, geologic surface data, and a collection of different reports of previous work and problems).

The geological surface data could be important, even when outcrops are far from the study area, because they regularly provide critical clues about depositional environment, facies distribution, structural aspects, etc.

The well data include log responses from each well, log analysis results such as effective porosity, fluid saturation, and lithology plus, when available, production data such as daily rates, cumulative production, fluid type, etc.

Finally, a conventional seismic reflection 3D volume and the first derived volume (adaptative coherence in this case) are generated.

Picking of horizons, delineation of faults and mapping will provide the first structural picture. Sometimes this is enough to identify a prospect; sometimes it isn't.

The second cycle (up to Interpretation II) involves generation of prestack depth-migrated data (to evaluate any possible misinterpretation in the reflectivity time model and to extract time-depth relationships for later depth conversion), generation of poststack acoustic impedance (as a tool to improve the interpretation of layer boundaries not seen on the reflectivity time model), and testing several attributes (to identify particular geologic features and also to be used later as input for SPV).

The cycle ends with a more sophisticated picking of horizons, faults, and identification of any remarkable geologic feature.

After a detailed review of logs and log analysis of existing wells, it was determined that a pseudo-GR volume was needed to visualize the potential of new locations for play I.

It was determined, from the well information, that a few have penetrated sand channels, some of which appear thick enough to constitute a commercial unit by themselves. Therefore a new probabilistic neural network volume was generated to account for "sand units thicker than ..."

Subsequently, some obtained volumes were converted to depth by taking advantage of the PSDM time-depth relationship.

The end of the third cycle is a detailed interpretation of plays I and II and a couple of new exploration prospects.

Substrategies regarding applying the appropriate interpretation procedure

This section discusses the key question of how a horizon will be interpreted. Figure 2, an example from an actual case, shows how the interpreter determines the geometry and filling of fluvial channels.

The sequence starts with picking the top and base of channels over four different volumes (acoustic impedance, pseudoporosity, pseudogamma ray, and pseudofacies). Channels boundaries had previously been detected from the coherence volume.

Horizons are later converted to grids to get surface continuity and then some rms horizon slides of facies volume are generated to produce the best images of geometry and facies.

In addition, the thickness of the channels is mapped by top and base subtraction.

The results are combined with the structural map and, finally, the porosity values inside channel boundaries (from the pseudoporosity volume) are extracted for channels above a known oil-water contact.

Conclusions

An interpretation strategy, which incorporates the changes that the interpretation work has undertaken during the last two decades, allows the interpretation team to integrate multiple data and communicates what they are planning to do.

Combining the available tools facing the challenging geological uncertainties now requires order and deep thinking before starting the job.

Contrary to the first impression, such planning saves time and money through the optimized use of available resources.

The strategy could be simple or quite sophisticated depending on the complexity of the uncertainties, and could involve a few days or many months.

Beginners are often reluctant to accept this concept proposal but it was found that, after a little experience with it, people acquire the skills to feel familiar with it and enjoy its benefits.

The main point of this article is that the systematic use of an interpretation strategy facilitates the horizontal and vertical communication for any O&G community, and accelerates progress toward the correct conclusion of any exploration/development analysis by avoiding obstacles that can be anticipated. TLE

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Acknowledgments: The author thanks Néstor Córsico, Andrés Boll, Gustavo Diez, Marcelo Santiago, and Osvaldo Carbone for reviewing this paper.

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