Software that Works the Way Petrophysicists Do

Collaborative, Efficient, Flexible, Analytical

Finding pay is perhaps the most exciting moment for a petrophysicist. After lots of hard work—gathering, loading, editing, conditioning, interpreting and analyzing—there is a chance to quantify the opportunity and recommend the best way to exploit it.

Over the past few decades, much new technology has been introduced to help petrophysicists find the pay. New downhole tools provide more complete data. Seismic data fills in the blanks between wells. Computers accelerate calculations. These improvements have all focused on improving the available data and its manipulation. Now attention has moved to helping the petrophysicist be more focused and effective, by delivering software that works the way petrophysicists do.

A high level view divides the work into four rough steps:

- Data gathering & loading
- Editing & conditioning
- Analysis
- Presentation

Each step is often collaborative and iterative with engineers, petrophysicists and geologists working together to efficiently produce the highest quality result.

Many companies today are standardizing workflows to ensure consistency of petrophysical processing results between analysts, across geographic areas and over time. Standardization also shortens training time and captures best practices. Yet, each petrophysicist has a preferred way of working through each step and steps can overlap. In order to support this, software must assist the petrophysicist but not insist on a rigid workflow. Standardization and best practices are enhanced when using software that works the way petrophysicists do.

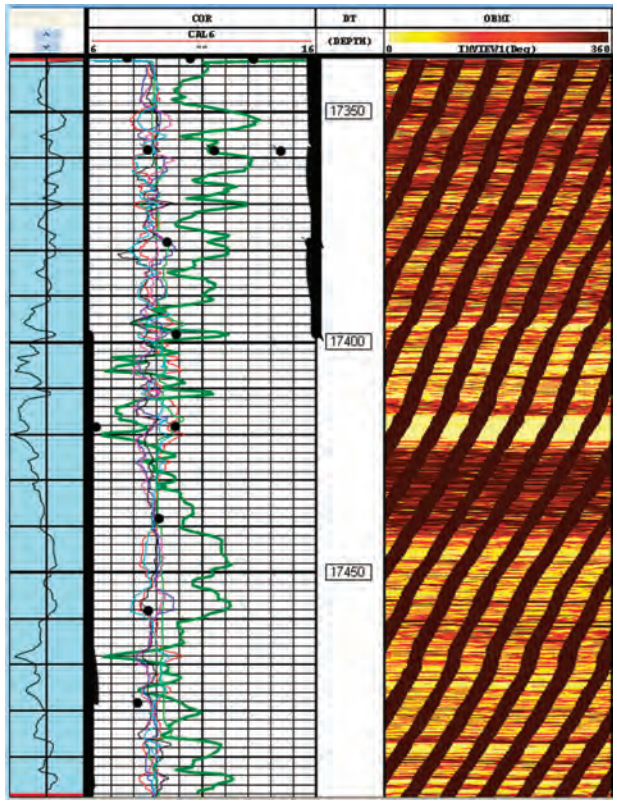

Figure 1: LogPlot with image log in one of the log tracks.

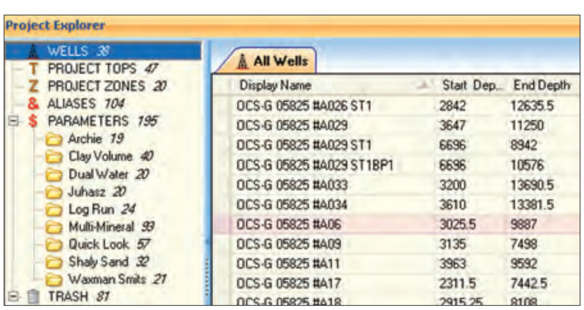

Figure 2: The *PowerLog®* database allows seamless, quick investigation and processing of even thousands of wells.

Data Gathering and Loading

The first step in petrophysical analysis is the gathering and loading of well data. This typically includes multiple logs from multiple wells, plus cores, drilling history, production history, and other data as available, such as seismic. Multiple team members may be enlisted to contribute data to speed the process.

Because the data may have been generated by different parties at different times, the petrophysicist usually has to work with several sources to get all the data. It is not uncommon for the data to have different units of measure, file naming conventions and header details. The data can also be incomplete or even completely wrong. All of these issues conspire to drag out the data collection period.

Once data is in hand, it is time to load it into the interpretation software. Because filenames are not likely to be consistent and meaningful, the petrophysicist will probably want to automatically impose a standardized naming convention—perhaps sequential—to groups of files during loading. Similarly, important header information must be automatically captured. When header information is missing—which is often the case—the software must present the header information in the most effective way for the petrophysicist to rapidly augment it. By pre-mapping header details based on various logging companies, the software can be even more effective. This header information can later be used in calculations and processes without manual intervention.

One of the potential complications of loading comes when the data is expressed in varying units of measure. Software that works the way petrophysicists do simply loads the data with its original units and

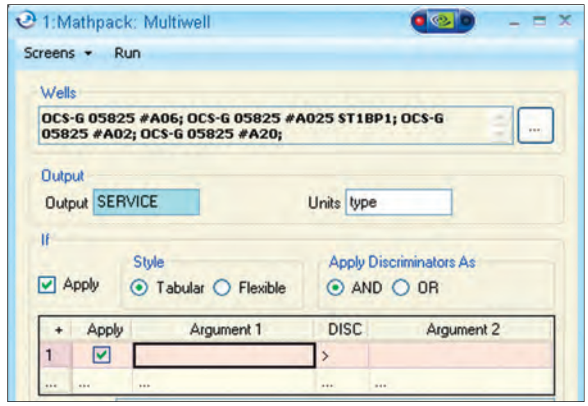

Figure 3: Each processor window can accept any number of wells and well groups for easy, quick multiwell processing.

enables depth sampling, interpolating and extrapolating later as needed. The units do not matter until the petrophysicist runs calculations or views the data in crossplots, histograms and log views.

Editing and Conditioning

As much as 85 percent of the well log analysis time is spent on editing and conditioning. During this step, the petrophysicist must iterate between visualizing the data and manipulating it. There is an inherent flow to this process, but each petrophysicist may approach the task from a different perspective. The goal of the step is to fix the problems in the data so that it is ready for interpretation. However, finding those problems is no easy assignment.

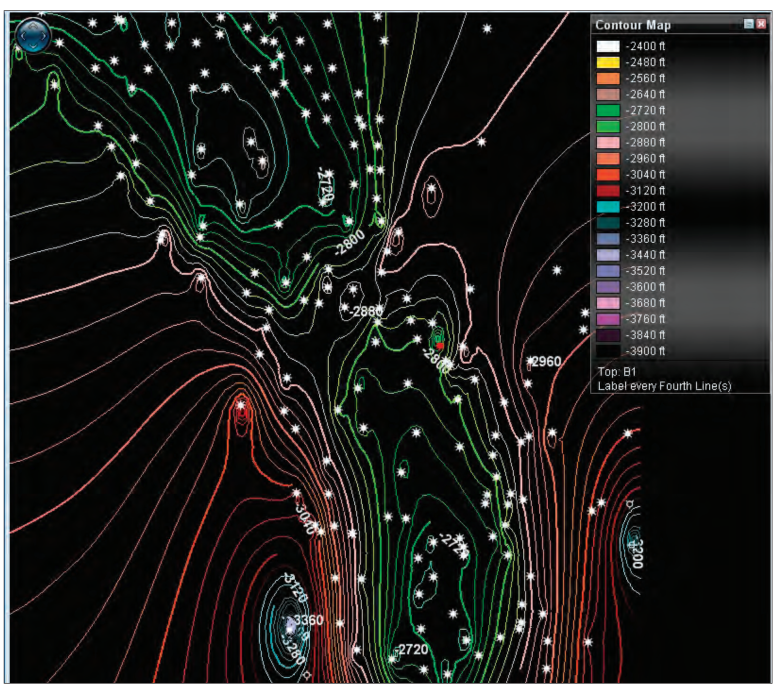

Figure 4: A Basemap shows spatial locations of wells on top of culture data and together with contours, attributes, etc.

As petrophysicists work through editing and conditioning they use visual tools and processors or calculators. While there must be great flexibility, there are definitely tools and calculations that are commonly used. These should be easy to identify and access from the software, and should be organized in a way that reminds the petrophysicist of related options.

Visual tools include log editors, base maps, crossplots, histograms, and tabular listings. Petrophysicists usually work with data for multiple wells, so these tools must be capable of displaying data from multiple wells. Petrophysicists may also want to see different views of the same data, such as a crossplot overlaying a histogram. With experience, petrophysicists will also have specific overlays they want to use, such as points and polygons representing various minerals, that can then overlay on the crossplot of the well under review. These are just a few examples of how petrophysicists need to view data and therefore what the software must support.

Visual tools are not just for viewing data. When a petrophysicist views a log plot and sees an error, for example, the petrophysicist will want to correct the problem right there. If tool calibration is off in one well, the petrophysicist should be able to fix it visually through a bulk shift and/or gain shift. The software should support selecting intervals to review—for example sand and shale—and then allow manual or automatic normalization. Throughout the editing process, decisions should be revocable, making it easy for the petrophysicist to experiment without worry. An audit trail of all edits should also be automatically compiled so that weeks or months later the petrophysicist can know definitively what was done to the logs.

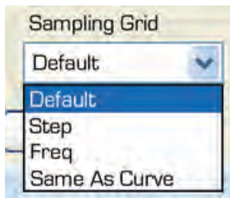

Figure 5: Users work with log data at a project step, a step selected for each processor, or the step of a selected curve.

The data behind the visual tools is also available for edit and review. Petrophysicists need to move easily between the data and its visual representation. For example, wells displayed on a map should be selectable such that the data for those wells is instantly displayed in a table. A map search for a value range of an attribute such as mud resistivity should find and display all the relevant wells. Similarly, the petrophysicist should have access to the equations behind a synthetic curve to paste into a MathPack for further processing.

Processors and calculators used for temperature conversion, environmental correction, and pre-interpretation calculations are often common to many wells within a field. Templates for these processes can be used in batch mode to help automate as much of the conditioning as possible. This ability to batch templates is important in later interpretation and modeling steps as well.

Petrophysicists spend a great deal of time on editing and conditioning. Software that works the way they do can relieve frustration while improving productivity and focus.

Petrophysical Analysis

Once editing and conditioning is complete, the petrophysicist can begin to discover what is in the reservoir. Template crossplots of neutron/density, density/sonic, and Pickett Plots, for example, provide information about mineralogy and fluids. Similarly, multiple logs displayed in a single logplot track can also identify and highlight rock and fluid profiles.

Facies Classification

An important step in the analysis is the identification and classification of facies. This can be done by selecting points on the log and assigning electrofacies classes. To double check the results, the petrophysicist can compare to relevant crossplots and neutron-density plots. Points out of place can be moved on either the crossplot or the logplot. Missing logs can be created and imperfect logs can be reconstructed using this method.

Capillary Pressure

To identify the relative fluid distribution and height above free water, petrophysicists often need to perform capillary pressure analysis. This process examines the pressure within the pores, which represents the difference between gas/brine, gas/oil or oil/brine concentrations.

During analysis, various electrical properties are determined along with the effect of conductive clay minerals to adjust saturation. Petrophysicists prepare porosity and permeability crossplots. Permeability transforms are revised after water saturation has been calculated and calibrated to capillary pressure. Original and dated gas/oil and oil/water contacts are determined to define gross intervals adjusted for capillary pressure and checked against production and test data.

Statistical Mineralogy

Petrophysicists may need to evaluate complex and varied minerals. A probabilistic model is used to calculate lithology, mineralogy and porosity plus reconstructed versions of all the input curves. The input data could come from typical curves, well logs or computed curves.

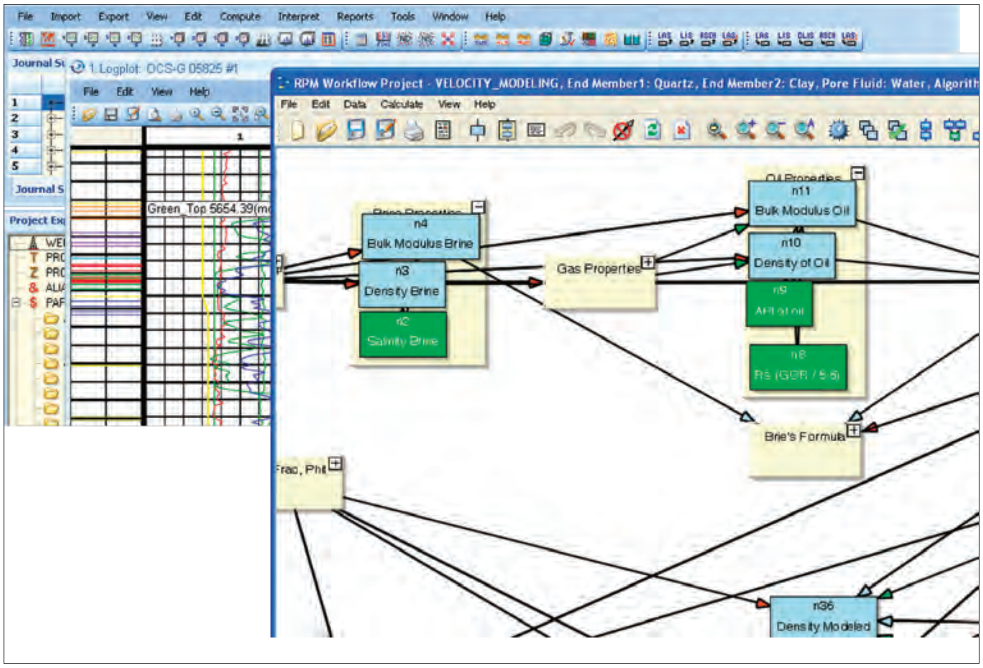

Figure 6: The *Rock Physics Model* add-on works seamlessly with all other processors and viewers to compute elastic properties, model compressional and shear velocity, etc.

Depending on the data available and the outputs required, the petrophysicist may need to solve a balanced, over-determined or under-determined model. Over-determined models have more logs than required to calculate the mineral volumes, in which case the model must create a best fit using the Maximum Likelihood Estimate of mineral fractions. In contrast, under-determined models do not have enough logs to compute all fractions at once. This more common model relies on the following techniques:

- Sequential Models (Prior Matrix)
- Alternate Minerals
- Alternate Matrix
- Computed Data Input

Linear response equations compute much faster than non-linear models. From this analysis, petrophysicists can obtain a model of mineral distributions in zones of interest.

Rock Physics Modeling

To build a rock physics model of the reservoir, petrophysicists need to go beyond the lithology of petrophysical analysis to elastic properties derived using rock physics. If sonic and shear logs are not available, synthetic curves are used. The goal is to construct a model that is consistent with both basic physical principals and the petroelastic model.

Rock physics may be as simple as establishing empirical relationships between rock properties or as complex as poro-elastic numerical modeling. The sophistication of the modeling will depend on the objectives and the quality and availability of data. Typical objectives include:

- Quality control of the measured elastic logs
- Quality control of petrophysical interpretation
- Synthesis of elastic logs
- Correcting logs for invasion effects and dispersion
- Scenario modeling
- Establishing a framework for interpretation of seismically derived elastic properties

To work the way a petrophysicist works, software must tightly integrate rock physics and petrophysics, so that processes, parameters and models are as consistent as possible. This results in a much more reliable analysis. The accuracy and consistency of petrophysical and rock physics models determines the quality and reliability of all subsequent evaluation.

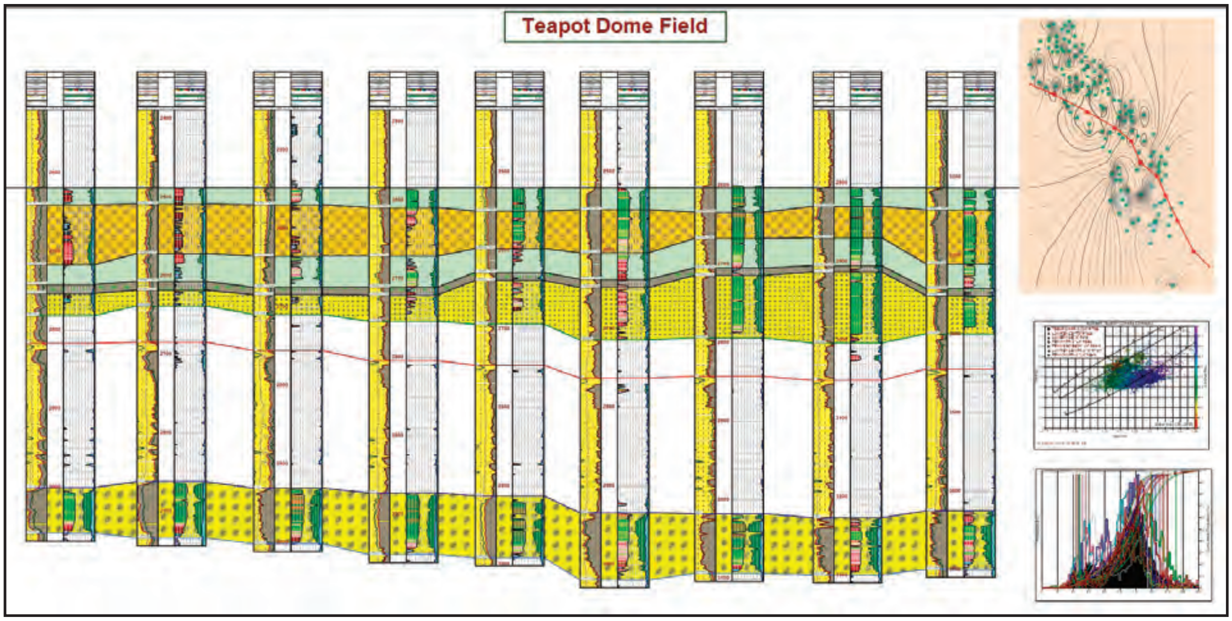

Figure 7: Collage of Teapot Dome Field wells, including base map, crossplot and histogram.

When petrophysics and rock physics are performed simultaneously, differences between models used and results produced are minimized or eliminated. Software must help petrophysicists build one model that is truly consistent with all the data and with the lowest uncertainty.

Presentation

Once the analysis is complete, findings must be reviewed with peers and presented in a convincing manner. This presentation can be challenging, because the analysis typically spans multiple zones within multiple wells and includes multiple sources of input. The final version of each well needs to be correlated to other wells and presented in a way that best communicates the interpretation. In the old days, this was done by assembling and pasting various logs onto a large pasteboard. Now, petrophysicists expect to be able to do this in software and present directly from the computer or output a collage to a large format printer.

Included in the presentation should be logplots, histograms, crossplots and images. Tops in the logplots should be visually connected to adjacent wells so that the collage provides the best support for the interpretation it describes. In this way, petrophysicists can effectively communicate their findings in a way that highlights their conclusions and moves the audience to action.

Summary

Petrophysicists face many challenges in well log analysis. They shouldn't have to wrestle with software to get the analysis done. Improvements in data acquisition and raw analytical compute power have increased the completeness of models. Now software is increasing efficiency and accuracy in modeling by supporting the way that petrophysicists work.

Introducing PowerLog

PowerLog® is used every day by petrophysicists, geologists, reservoir engineers and others involved in oil field appraisal and development. Unlike other products on the market, PowerLog works the way you do—letting you drive the order of actions and the amount of guidance provided. You can work on multiple wells and data physically located anywhere in the world, and as an individual or as part of a team. PowerLog is truly multi-well and multi-user. Its ease of use and intuitive interface are a testament to the feedback customers have provided over the past 20 years.

The multi-well database in PowerLog makes analysis for field-wide studies easy and fast. PowerLog provides effortless access to even thousands of wells, all of which are immediately available for single or multiwell operations. PowerLog helps keep data neat and organized, ready for swift action.

The PowerLog multi-user capability allows teams to work on a project or even on a single well together, helping them to collaborate without getting in each other's way. The geologist can pick the tops, the engineer can create the zones, and the petrophysicist can analyze the logs in this new collaborative environment.

The base map in PowerLog provides spatial visualization of the wells in the field including deviated wells, allowing you to quickly select wells for analysis or display. Posting of attributes, contouring, and culture data combined with logplots, images and supporting graphs enables management-quality presentation graphics to explain your field data and interpretations.

New multi-well and multi-zone containers are attached to each type of processor (Mathpack, Basic Calculations, Interpretations, etc.) so that users can do batch processing right on each calculation window. Users modify and apply their newest Sw parameter set to hundreds or thousands of wells all from a single window with a quick drag-drop of wells and click of the RUN button. Data sampled at coarse step size coexist with borehole image data and very irregularly sampled core data all in the same database, quickly and easily accessed for viewing and processing. The petrophysicist can elect to view or work with the data at any step desired.

PowerLog user programs now bring the full functionality of Microsoft Visual Basic® toolbox to the user while still offering the simple interface found in previous versions of PowerLog.

PowerLog has a Rock Physics Module that is tightly integrated with the petrophysical analysis, ensuring consistent models and parameters between the petrophysics and rock physics modeling. For more information, see "Benefits of Integrating Rock Physics with Petrophysics."

PowerLog also has modules for statistical mineralogy, facies classification and capillary pressure interpretation.

For more details on PowerLog and its advanced analysis modules, visit www.cgg.com/jason.

