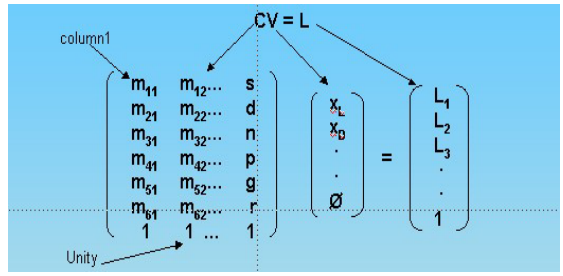
PETROPHYSICS

Matrix-Inversion Lithology and Porosity Modelling

Uses: mixed lithology (carbonate, evaporates, etc), tight gas sands, shale-gas

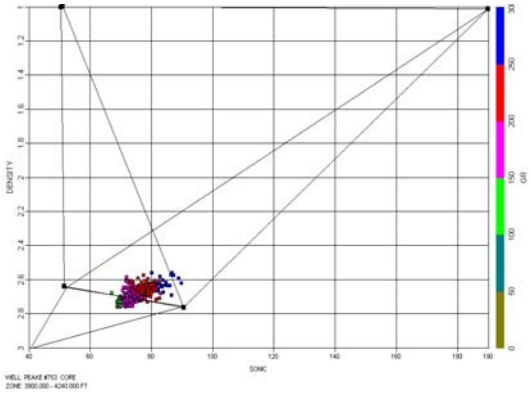
The inversion process attempts to determine the degree of interaction between matrix porosity and the fracture (macro and micro) system through the statistical estimation of connected and isolated (no-flow) porosity layers along with their lithologic composition using linear and non-linear matrix inversion techniques. The figure to the right depicts a simple matrix algebra process similar to the Hunt Wallace solution. Matrix algebra solutions have the advantages of fast processing speeds and output diagnostics to the user as well impressive predicting capability.

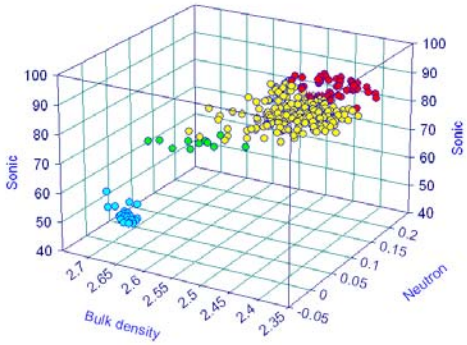


The Model Process

The crux of the modeling technique is to design valid criteria for objectively determining the most likely solution. In order to minimize error, the matrix inversion model must have more known elements (log responses) than unknown elements (porosity and lithologies). Optimizing and combining petrophysical response equations from several log measurements using geologically **constrained matrices** has shown to be an extremely effective approach. In other words, other inputs such as core descriptions, cutting descriptions, etc. help to define the dominant lithologies so that more time can be spent on solving for porosity type. Confidence intervals are used to define a region around an estimated result in which the true value of the result will most likely occur.

Log response coefficients for each tool and lithology chosen are defined from core-calibrated 2-dimensional and 3-dimensional cross-plots as depicted below. The crossplots also help the analyst to visualize the end result. The Analyst uses scalable lithology lines with interactive capability to move matrix and fluid end-points to mimic lithology volumes observed from X-ray Diffraction (XRD) volume percentages.





Estimates of isolated porosity (ISOPOR) and connected porosity (PORCN), as part of the matrix inversion method, in part; depend on the degree of separation between resistivity log measurements and the log response from acoustic and nuclear log measurements. This is integrated into the inversion process to help delineate connected versus isolated porosity type. Electron scanning microscope (SEM) measurements can aid in the detection of these microfracture features, if available.

The probabilistic matrix inversion software is designed to solve balanced and over-determined model sets. The results become more robust when knowns (measurements) exceed unknowns (rock properties). The inversion model compensates for the non-linearity of the logging tools at low porosities.

End-points to the matrix inversion model are refined until a convergence has been obtained. Results are accepted when error and standard deviation have been minimized

Evaluating Unconventional Shale Reservoirs – An Improved Assessment of Reservoir Properties Using Traditional Logging Suites

Hydrocarbons from unconventional sources, such as, (black, organic-rich) shale is rapidly becoming a major player to the World energy mix. Literally hundreds of thousands of wells have been drilled and completed throughout the World in basins that contain unconventional reservoir plays. Several of these wells are being exploited for its hydrocarbon but most are left behind pipe in order to recover hydrocarbons from more conventional reservoirs.

Now, with the advances of horizontal drilling, improved hydraulic fracturing techniques, use of specialized core laboratory hydrocarbon content modeling, and modern log-imaging technology, higher volumes (rates) and more accurate assessments of hydrocarbon-in-place have made these plays economically attractive. However, in the past the Industry has drilled several wells through the shale for other conventional targets. *How does one evaluate a shale's potential given a mudlog (limited availability), and a suite of more traditional wireline log measurements for these wells? Another issue to consider is how does an Operator overcome the fact that his now detected large aperture fracture from image logs is now filled with completion cement?*

Wallace International focuses on a more rigorous assessment of traditional log measurements from both new wells, specifically drilled for organic-rich shale, and existing conventional wells that are at the end of their economic life and may be a candidate for re-completion in the organically rich shale. Another words, reclaiming by-passed hydrocarbons already behind pipe. **The key here is to detect the micro-fracture network in the shale, and not just the large aperture fractures and the matrix porosity with open pore throats.**

Matrix-Inversion (statistical) modeling uses linear and non-linear matrix algebra as the crux of the process. The model requires that more known elements (log responses) exist than unknown elements (porosity and lithologies). Optimizing and combining petrophysical response equations from several log measurements using geologically constrained methods has shown to be an extremely effective approach. **This assessment addresses the identification of: potential zones of deformation, possible porosity type, estimates of lithology and a prediction of frac-height. The probabilistic petrophysical modeling concepts presented can also be compared and calibrated to the high-resolution resistivity and/or acoustic image log measurements and interpretations**