Tight Formation Evaluation

The major goal in tight oil/gas evaluation is to maximize field economics, which may be accomplished by two competing strategies:

1. improving per well rates and reserves
2. reducing well construction and completion costs

To find the optimal solution, it is imperative to improve the understanding of reservoir architecture, especially the sweet spot distribution and the reservoir compartmentalization.

We have divided our Tight Formation Workflow into two main components:

- Well Productivity Drivers Evaluation
    - Rock Typing
    - Natural Fracture System
    - Reservoir Performance Prediction

- Well Construction Cost Drivers Evaluation
    - Well Configuration
    - Drilling Efficiency
    - Completion Efficiency

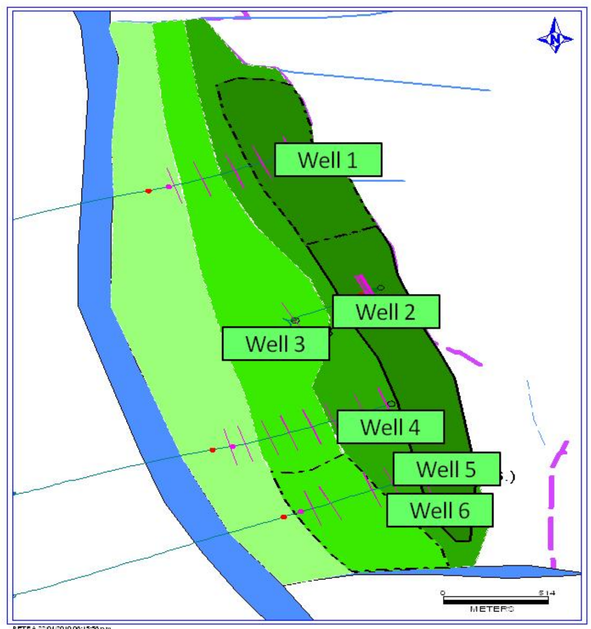
Well Productivity Drivers Evaluation

Well productivity driver evaluation starts with the identification of key geological parameters using seismic, geological and petrophysical data. Rock typing and fracture characterization are then performed to review comprehensively rock characteristics to understand flow unitization by defining sequencing, quality, geometry, and spatial distribution of these different rock bodies. Finally, we link the rock type / fracture network spatial distribution to reservoir productivity, pressure and volumetrics, allowing us to relate static reservoir description with dynamic performance, and to outline the distribution of productive trends.

Sweet spots, concentrated high quality reservoir, and reservoir compartmentalization represent the fundamental criteria for well placement and reservoir performance prediction.

In this process we recognize several key elements of interest which require a thorough assessment by a multidisciplinary team:

- Lithology and reservoir facies
- Porosity and fluid saturation
- Stratigraphic units and fault blocks
- Permeability and fluid mobility
- Natural fracture characterization
- Stress states and stress dependent properties
- Productive interval identification

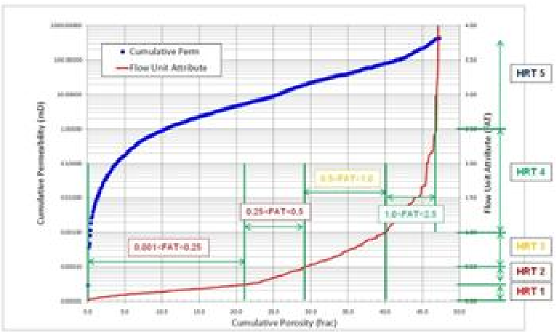


Sweet spots identified from integrated tight gas productivity evaluation

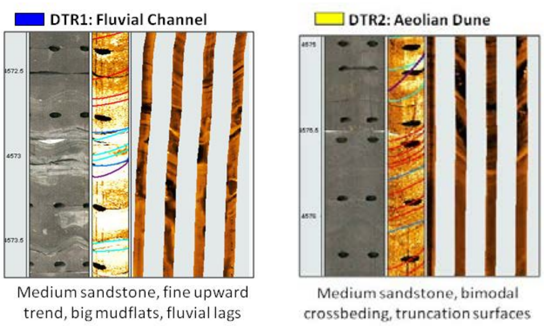
Rock Typing

The definition of the sweet spot(s) is a fundamental step for the well placement process as it reduces the uncertainty in prediction of reservoir performance, a critical factor in tight reservoirs. An approach called Rock Typing is used to create a systematic and consistent management system for all information available, which ultimately leads to definition of the spatial distribution of the various building blocks of the reservoir system.

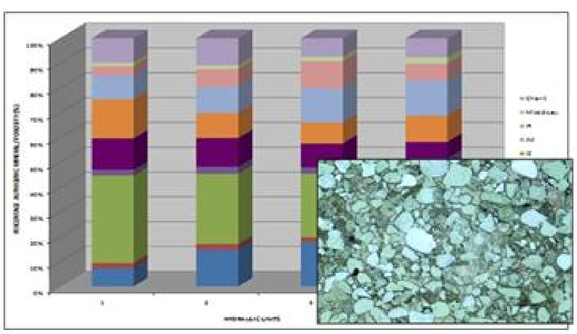
There are three categories of rock typing, namely depositional, petrographic and hydraulic rock typing. The comprehensive approach carried out by Task Fronterra involves different scales and quality/type of information in a consistent fashion (see also our ROCK TYPING flyer).



Modified Lorenz plot for delineating hydraulic rock types



Correlate depositional rock types to flow behavior

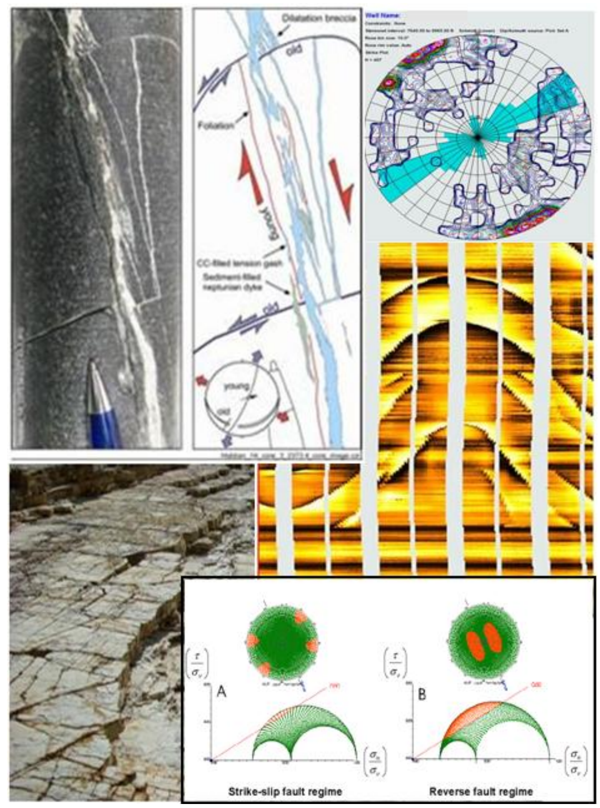


Correlate petrographic rock types to flow behavior

Natural Fracture System

The impact of a natural fracture system in tight oil/gas reservoirs depends upon three mechanisms: (1) natural fractures may provide high-perm conduits, enhancing productivity potential; (2) they may lower sweep efficiency by increasing heterogeneity in the reservoir; and (3) they may limit or enhance well stimulation performance.

Integrated natural fracture analysis involves the identification of fracture type, attitude/description and fracture distribution. It is imperative to understand how borehole-corrected fracture density is related to the *in-situ* stress field, tectonic events and rock matrix properties. In Task Fronterra, we combine data from seismic, outcrop, cores, image logs and open-hole logs to characterize natural fracture systems. Geomechanical modeling and dynamic validation complement our efforts, so that reservoir performance prediction, well placement and stimulation design may be optimized.

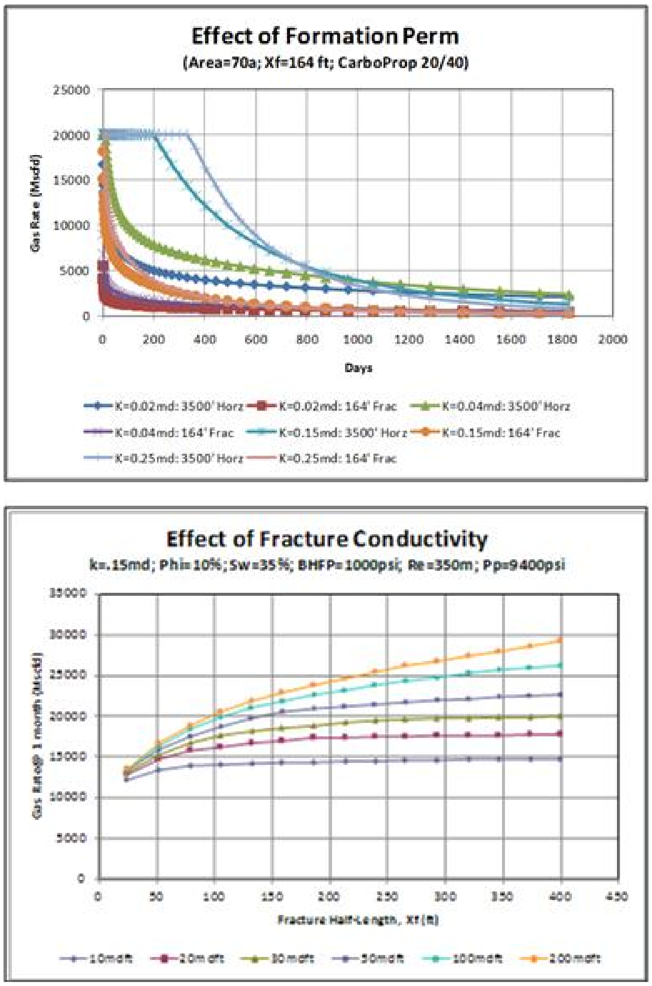


Multi-disciplinary fracture system characterization

Reservoir Performance Prediction

After the careful study of geological settings and the identification of sweet spots and reservoir compartmentalization, the next step in designing a well completion is to evaluate reservoir flow potential at no damage conditions. We have experienced countless industry examples that while many under-producing wells were blamed on completion design, low production often related to poor reservoir quality because of the lack of an integrated geological evaluation.

A rigorous and integrated reservoir conceptual model and characterization allows a realistic representation of reservoir performance. Dynamic modeling allows for selecting the combined set of parameters, fracture length and conductivity, leading to an optimal stimulation design, hence benefiting field economics.



Production prediction sensitivity analysis

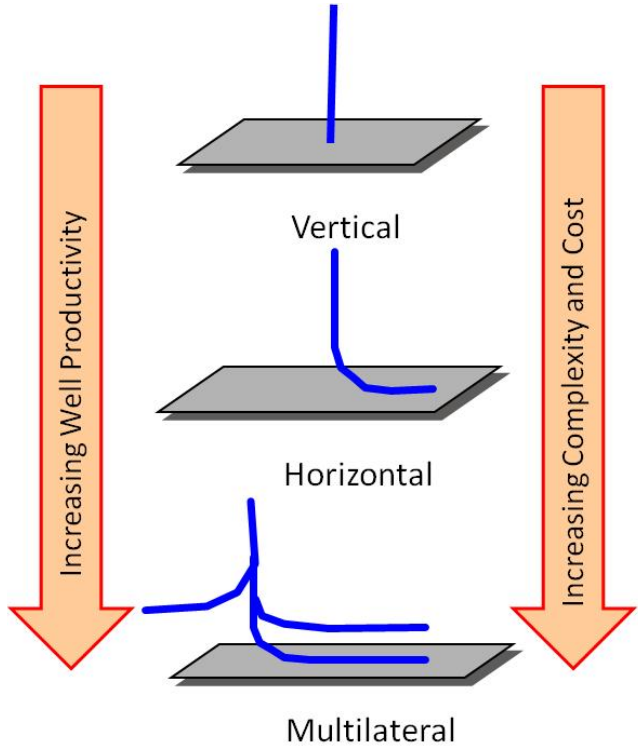
Well Construction Cost Drivers Evaluation

There are six key evaluation steps to determine well construction cost drivers (well configuration, drilling efficiency and completion efficiency):

- Data gathering and drilling events analysis
- Mechanical properties evaluation
- Pore pressure and *in-situ* stress determination
- Geomechanical model construction, calibration and validation
- Borehole stability analysis
- Fracture design, containment, orientation and conductivity.

Well Configuration

The definition of well placement and configuration takes into account the objective zones in terms of zone thickness, permeability and porosity, and fracture network propagation. Careful zone selection and well configuration allows for an effective depletion of the sweet spots, achieves desired well productivity to the full potential and optimizes well construction cost.



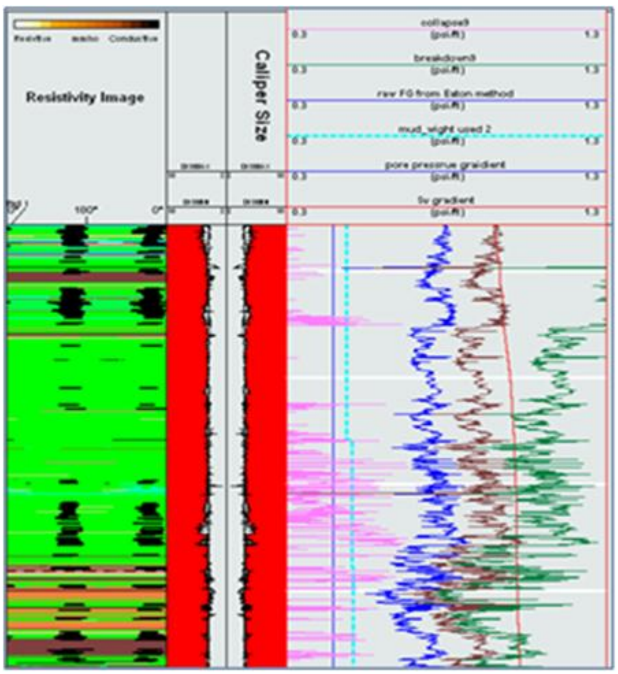
Drilling Efficiency

Drilling costs can be seriously affected by problems related to loss of circulation, wellbore instability, stuck pipe and kicks. These issues can be prevented by a better understanding of the geomechanical model, pore pressure prediction and borehole stability analysis.

Formation geomechanical properties are derived from logs, but it is also important to calibrate them with lab data and field tests for a robust geomechanical model that is useful for continuing studies.

Pore pressure prediction starts by determining the normal compaction trend lines on logs, with the calibration/verification from direct measurements or indirect indicators. This analysis identifies critical zones that pose potential hazards, so that preventive measures can be applied during design and while drilling, improving the drilling efficiency.

Stress orientation and magnitude, together with the present stress regime, contribute significantly to borehole stability. Borehole breakouts and induced fractures provide the best indicators for *in-situ* stress orientation. The stress fields derived from open-hole logs are finally calibrated with drilling events. This analysis prevents hazardous drilling events to occur and reduces the unproductive time, significantly improving drilling efficiency.

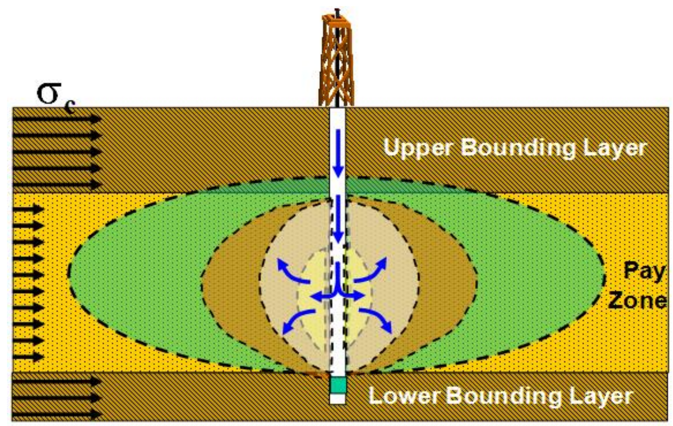


Borehole stability analysis with drilling event validation

Completion Efficiency

Well completion represents the connection between the reservoir, the wellbore and the surface facilities. A good completion scheme can enhance the production of the reservoir while poorly designed completions can severely limit reservoir production.

The goal of the completion then is to optimize reservoir production values versus the cost of implementing the completion itself. The three drivers that impact hydraulic fracture efficiency include: (1) fracture orientation, to increase contact with natural fractures and reduce the risk for screen-out; (2) fracture containment, to provide means to reach a desirable fracture geometry, to increase the surface contact between the reservoir and the well and to reduce the risk for run-away fractures; and (3) fracture conductivity, to provide the necessary conductivity as the product of fracture width and proppant placement.



Schematic illustration for fracture containment

<u>Summary</u>

Task Fronterra Geoscience has developed an effective and practical workflow to evaluate and develop tight oil/gas reservoirs. This workflow integrates all relevant disciplines: from geology, geophysics, petrophysics to geomechanics, reservoir engineering and economic optimization.

The method places special focus on reservoir productivity and drilling and completion drivers, for a better understanding of the reservoir. This then serves as the foundation to validate hydraulic fracturing efficiency and to improve overall reservoir economics.

Task Fronterra Geoscience is a global independent provider of industry leading, integrated geoscience solutions, from single well analysis to complete reservoir studies.
Some tasks described herein may be performed by one or more associates.