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Fractured, tight gas reservoirs
Impact of uncertainties on the development plan

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As all fractured reservoirs, tight gas fractured reservoirs are very unpredictable if not extensively studied with a dedicated methodology. However, unlike conventional fractured reservoirs, their ability to produce hydrocarbons is heavily dependent on the understanding of fractures geometry and dynamics and their consequences on the development plan. This statement will be illustrated by the following case study.

This work was performed by Gaz de France at a very preliminary stage of appraisal with little data available. Our aim was to evaluate the possible behaviour of the field depending on the subsurface uncertainties, to identify the necessary information to increase our understanding of the field dynamics and to quantify the amount of budget economically justifiable for the forecasted data acquisition program.

The area of interest is a 7 x 7 km square. It was drilled by 8 wells. The compact paleozoic sandstone reservoir is low porosity (< 5%) and low permeability (from 0.01 to 1 mD). The matrix is homogeneous and only one rock type was considered. The reservoir is gas and condensate bearing. It has been mostly affected by several distension phases along the paleozoic and mainly structured during the Hercynian major events with inversion and strike-slipping features. This complex tectonic framework controls various fracture directions and contrasted dynamic properties.

The study methodology is multidisciplinary and has integrated:

- our regional knowledge of the reservoir area and its tectonic style,
- static data (including available seismic and image log data),
- dynamic data (including well test data).

A first 3D model was built which compiled static properties calibrated on seismic and well data. Fractures dynamic properties were then calibrated on well test data and the fracture model was translated into a reservoir model. The fracture model was designed with the FRACA™ software, the reservoir model with ECLIPSE™.

The static fracture characterization includes several steps such as:

- fracture sets identification at the well scale which implies a good understanding of the tectonic framework for modelling purposes,
- correlation of fracture sets properties (orientation and density) to field scale information (seismic geometrical attributes such as curvature and dip),
- calibration loop on well data of the static fracture model.

Several static models, i.e. fracture distribution scenarios, were set up from our interpretation.

The dynamic fracture characterization also includes several steps at the FRACA ™ cell scale:

- building of a Discrete Fracture Model (DFM) i.e. an object oriented model in which each fracture is individually modelled. DFMs were created for a limited amount of selected cells (Figure 1),
- fracture dynamic properties calibration on well test data (and/or PLT if available which is not the case here),
- equivalent properties computation. At this stage, a permeability tensor representative of the cell dynamic behaviour is computed.

This process is repeated on a sample of cells of the FRACA™ model, selected with the experimental design theory that allows accurate modelling and therefore accurate interpolation of the results.

Depending on the static reservoir model, i.e. scenario, several dynamic characterizations were possible. However, each one was calibrated on the well data available and therefore all models are comparable in the calibration well cells.

The FRACA™ model translation into an ECLIPSE™ model requires a two-stage work:

- grid construction, of which orientation is very important for flow computation accuracy as fractured reservoirs are very anisotropic,
- upscaling of the fractures dynamic properties, from the full permeability tensor to transmissivity data.

This work can be performed in order to characterize either a dual medium model or an equivalent, single medium model. Dual medium models are usually associated with fractured reservoirs although they are not specific. In our case, a single medium model was used as multi phase flows were not expected in the reservoir.

The field development was supposedly based on a 10 wells drilling program. The well locations were chosen as to be optimised according to one selected fracture scenario. A reservoir simulation was run for all scenarios, with the same imposed plateau and a cut-off flow rate at the end of decline. Well locations were maintained for all simulations. Results are dramatic as the plateau duration can vary from 1 to 10 and the final recovery from 1 to 2 depending on the scenario.

Finally, a simulation was run for the extreme fracture distribution scenarios in order to evaluate the impact of a “worst well locations case”. The wells were moved, no more than 200 meters away from their initial position, in order to assess the impact of an inappropriate well location choice. Comparing the “best well locations cases” (e.g. GFSWARM4, Figure 2) and the “worst well locations cases” (e.g. GFSWARM4C, Figure 2) results in a 1 to 4 ratio for the plateau duration and 1 to 1.3 for the final recovery.

Economics were run on different cases in order to quantify the impact of the computed differences depending on the scenario and the well locations. The impact is very sensitive to the chosen scenario and, in our case, can change an economic project into an uneconomic project. Moreover, the cost of the fracture model understanding, that includes the completion of a fit-for-purpose data acquisition program and an extensive reservoir characterization study is largely paid by the potential cost of a wrong well location choice.

As a conclusion, the authors would like to stress the importance of multidisciplinary team work in geology, geophysics and reservoir engineering for such a study because of the interdependence of the static and dynamic models definition and calibration. They would also like to emphasize the impact of uncertainties in this kind of projects, both technically and economically, and to insist on the necessity of substantial data acquisition and extensive reservoir characterization prior to embark on a development plan (Figure 2).

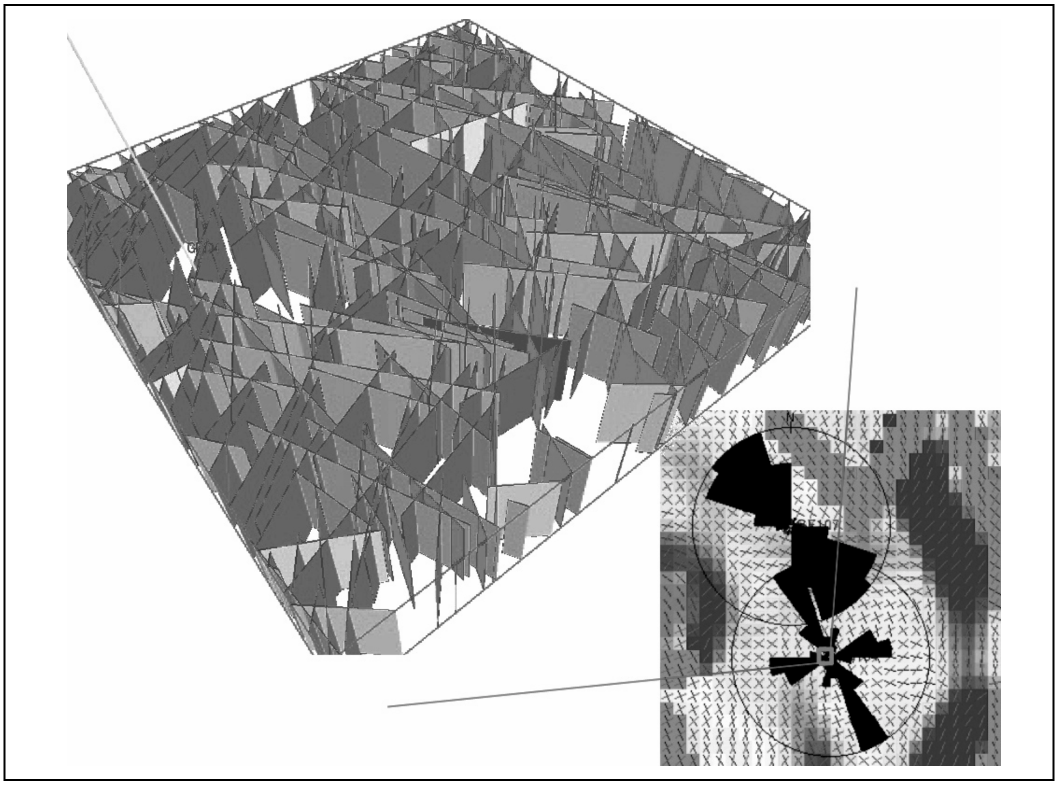

Figure 1 : FRACA™ model – Discrete Fracture Model (DFM) - This DFM was built in a cell intersected by a well from a cellular model (fracture density and orientation properties for different families). The rosettes show the actual natural fractures as compiled from the image log interpretations

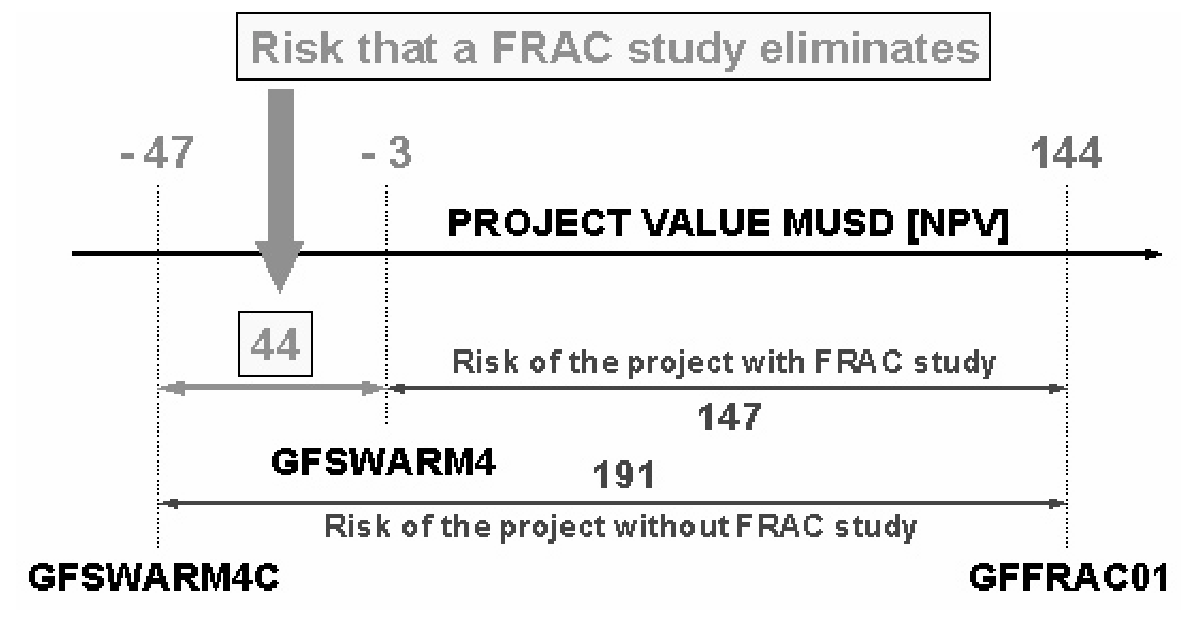

Figure 2 : Impact of uncertainties on a fractured tight gas reservoir production project and value of a fracture study