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Using Outcrop Data for Geological Well Test Modelling in Fractured Reservoirs

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SUMMARY

Outcrop fracture data sets can now be acquired with ever more accuracy using drone technology augmented by field observations. These models can be used to form realistic, deterministic models of fractured reservoirs. Fractured well test models are traditionally seen to be finite or infinite conductivity or double porosity - corresponding the fractures with or without matrix support. Using this simple field outcrop based geometrical model to generate typical well test responses for wells either intersecting fractures or well nearby fractures shows that such responses can occur in sequence as part as a diagnostic signature of naturally fractured reservoirs.
Introduction

Outcrop fracture data sets have been acquired and used to model the well test pressure response to understand how various ‘classical’ well test models might be related in natural systems. A recent review of fractured reservoirs (Spence et al., 2014) suggests that whilst well test and production data are an important aspect of fractured reservoir evaluation and model calibration (Delorme et al., 2014) there are limited examples of geological well test modelling of fracture systems due to the limitations of detailed fracture networks and challenges of setting up the numerical simulations to handle the matrix and fracture characteristics (Corbett et al., 2012).

Method

Gafsa basin is located in the central Tunisia (Fig. 1) and it separates between the Tunisian Atlas mountains in the north and Saharan platform in the south. An excellent exposures of two formations of fractured carbonate are existing in the chosen study area, including, Kef Eddour formation (Eocene) and Upper Berda Formation (Upper Cretaceous) (Bisdom et al, 2014).

An intensive amount of information has been collected, including the necessary fracture description such as fracture orientation, fracture length, size and density. In addition, thousands of fractures have been digitized (Bisdom et al, 2014). The digitized outcrop fracture data set was used to interpret the small scale deformation patterns and related them to the local ones through the fold (Bisdom et al, 2014). Linking small scale deformation to stresses helped to identify different stages of fracturing before and during the folding (Bisdom et al, 2014).

Kef Eddour formation, which is used in the current project model, has two systems of fractures perpendicular to bedding, each system has two groups of orientation separated by < 40° angle (Bisdom et al, 2014). The first fracture set has almost an orientation of (N-NW to S-SE) and the second fracture set has (E-NE to W-SW) direction (Bisdom et al, 2014), as shown in Fig. 2.

Figure 1; Location of the outcrop data set (a) Setting of the Gafsa basin (b) Enlargement of the red box area in (a) with the Alima anticline in the centre. Seismic lines indicated in red. Green star indicates a well (Bisdom et al., 2014)
Workflow

The fracture pattern identified in Fig. 2 was imported into a geological modelling package and matrix properties assigned following a geological well testing workflow (Corbett et al., 2012). The fracture model was set in a jacket of the effective matrix (Fig. 3) to ensure that the flow in fractures didn’t reach the model boundaries before inducing flow from matrix to fracture. The reservoir model is a double matrix reservoir and the objectives of the flow simulation was to explore varying well test responses to wells intersecting fractures and wells intersecting matrix with subsequent fracture flow.

Figure 2: Fracture set digitized from the outcrop for use in the well test simulation model.

Figure 3: Simulation Model: **Left:** Fracture set in the simulation model set in the matrix jacket. The fractures are propagated vertically through the layer in this model. **Right:** Reservoir Simulation Model showing pressure changes along the fractures and in the adjacent matrix.

The models were set up with a typical oil fluid and appropriate relative permeability curves for the fractures and matrix however this study was mostly concerned with the single phase (oil production) and pressure build-up after shut-in. The model was set up with 0.5 x 0.5m grid blocks after a sensitivity study. A matrix permeability of 8md and a fracture cell permeability of 10.4D was used for the base case simulations. Fracture opening is a very sensitive parameter in fracture modelling. It reflects how strong this fracture may influence on fluid flow. An open fracture of 1mm will has an equivalent permeability of \(8.3 \times 10^7\) mD using the formula \(k_F = \text{Aperture}^2 / 12\) (Geiger and Matthäi, 2012). Therefore, varying aperture will be used in the basic model to mimic the reduction of fracture opening in natural due to digenetic process, closing by cements, gouge, or compaction. Although in reality it would be impossible to have a fracture set having similar aperture in every fracture in the fracture network, a simple assumption of one aperture size in the whole fracture network will be assumed to simplify the calculations.
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Table 1: Different fracture aperture and the equivalent fracture cell properties in the model. Case C was used as the base case. Further details in Aljuboori, 2014

Results

Various scenarios of well placement were investigated. Fig. 4 shows the responses (pressure build-up and derivative) for wells in three different locations in the same model. All converge to the same late time behaviour of the matrix jacket and outer limits of the tested model. The characteristic double porosity response occurs in a very different time period when the fracture is intersected. Changing the matrix properties will alter the double porosity response but the distance from fractures is the most significant effect. This is to be expected as a result of wells only finding matrix in a fractured reservoir but with a set of parameters from a subsurface field a set of type curves could be produced to explore responses to various more realistic scenarios.

Conclusions

An outcrop fracture pattern has been used to generate fracture response through geological well testing approach. A well intersecting a fracture will show an infinite conductivity fracture response before the effects of the lower permeability matrix are seen and a double porosity system. The well intersecting matrix will see matrix radial flow followed by the double matrix response. This work has shown that using outcrop models and petrophysical properties a series of fracture response type curves can be generated for a matrix-fracture system. The classic “infinite acting” response and the “double porosity” well test responses can be seen as parts of a more general fractured reservoir response.
Figure 5: Time lapse pressure plots during a well test pressure build-up at various times identified by yellow dot on the derivative

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References