MADRID 2015
1-4 June 2015 | IFEMA Madrid

We N118 01

Using Outcrop Data for Geological Well Test Modelling in Fractured Reservoirs

F. Aljuboori (Heriot-Watt University), P. Corbett* (Heriot-Watt University), K. Bisdom (Delft University of Technology), G. Bertotti (Delft University of Technology) & S. Geiger (Heriot-Watt University)

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).

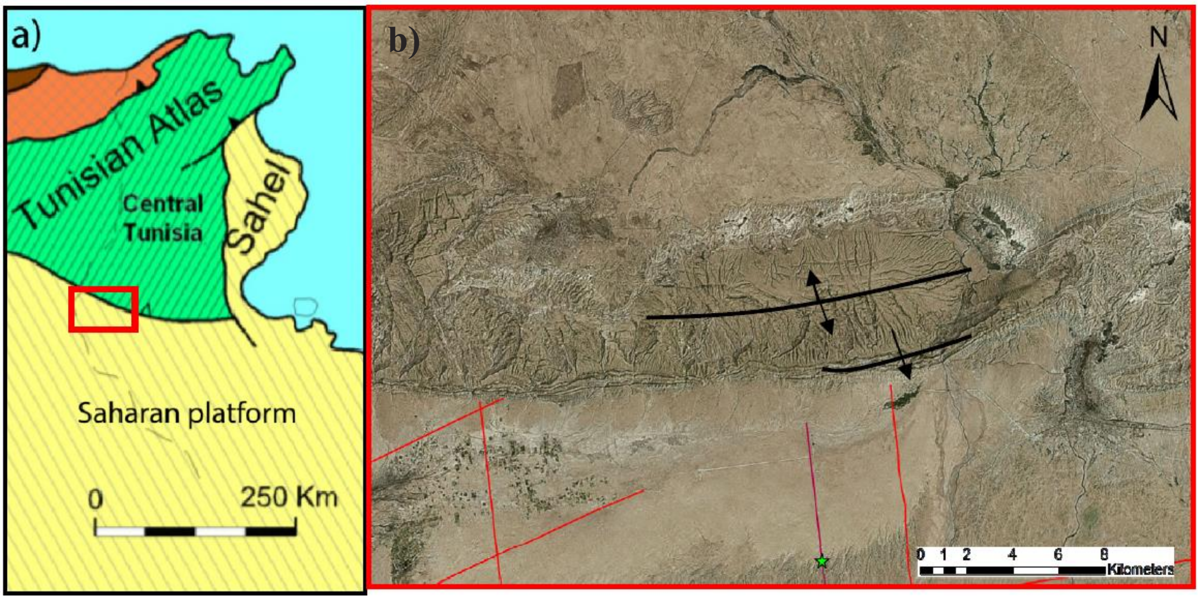

Figure 1; *Location of the outcrop data set (a) Setting of the Gafsa basin (b) Enlargement of the red box area in (a) with the Alima anticline in the centre. Seismic lines indicated in red. Green star indicates a well (Bisdom et al., 2014)*

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.

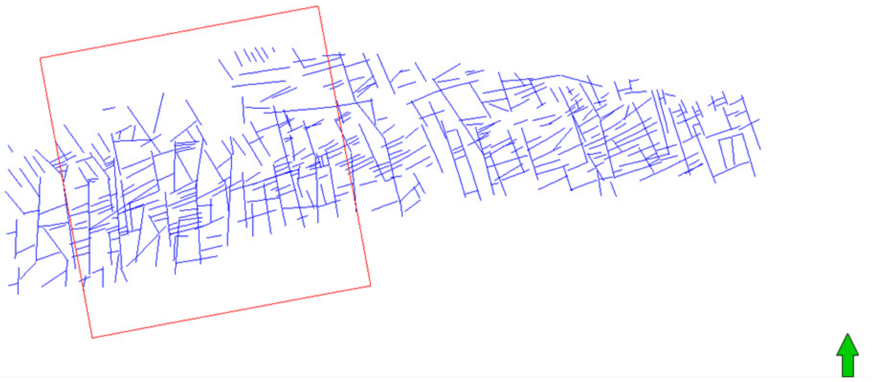

Figure 2: *Fracture set digitized from the outcrop for use in the well test simulation model.*

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.

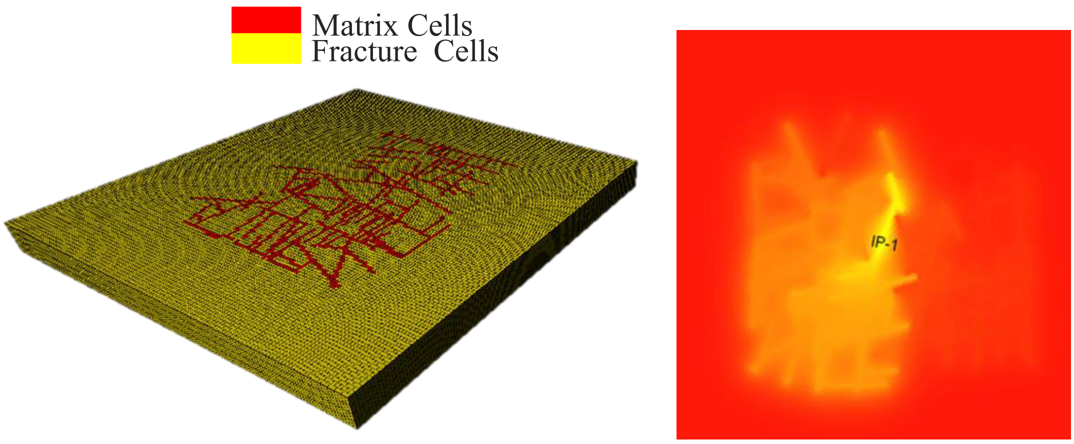

Figure 3: *Simulation Model:* ***Left:*** *Fracture set in the simulation model set in the matrix jacket. The fractures are propagated vertically through the layer in this model.* ***Right:*** *Reservoir Simulation Model showing pressure changes along the fractures and in the adjacent matrix.*

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 8.3×10^7 mD using the formula (k_F = 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.

Model	*Aperture (m)*	k_{Frac} *(mD)*	k_{cell}	φ_{cell}
A	0.001	83 333 333	83 333	0.001
B	0.00075	46 875 000	35 156	0.00075
C *(Base Model)*	0.0005	20 833 333	10 417	0.0005
D	0.00025	5 208 333	1302	0.00025
E	0.0001	833 333	83	0.0001
F	0.000075	468 750	35	0.00008

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.

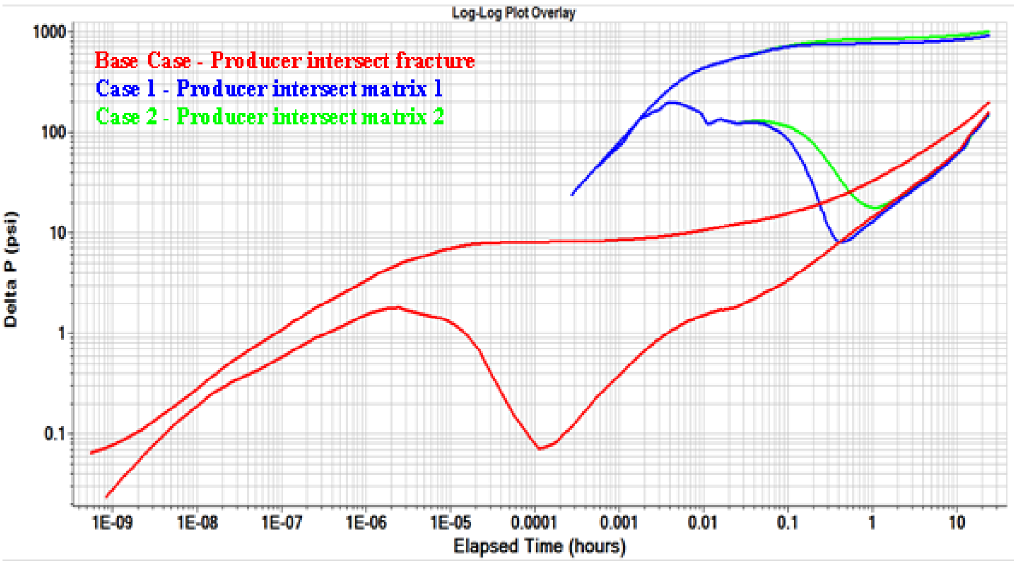

Figure 4: *Well test pressure build-ups and derivative. The well intersecting the fracture (red) shows a classical infinite acting fracture response. The other two cases (blue and green) show response to a well placed in the matrix and the responses show classic double porosity response.*

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.

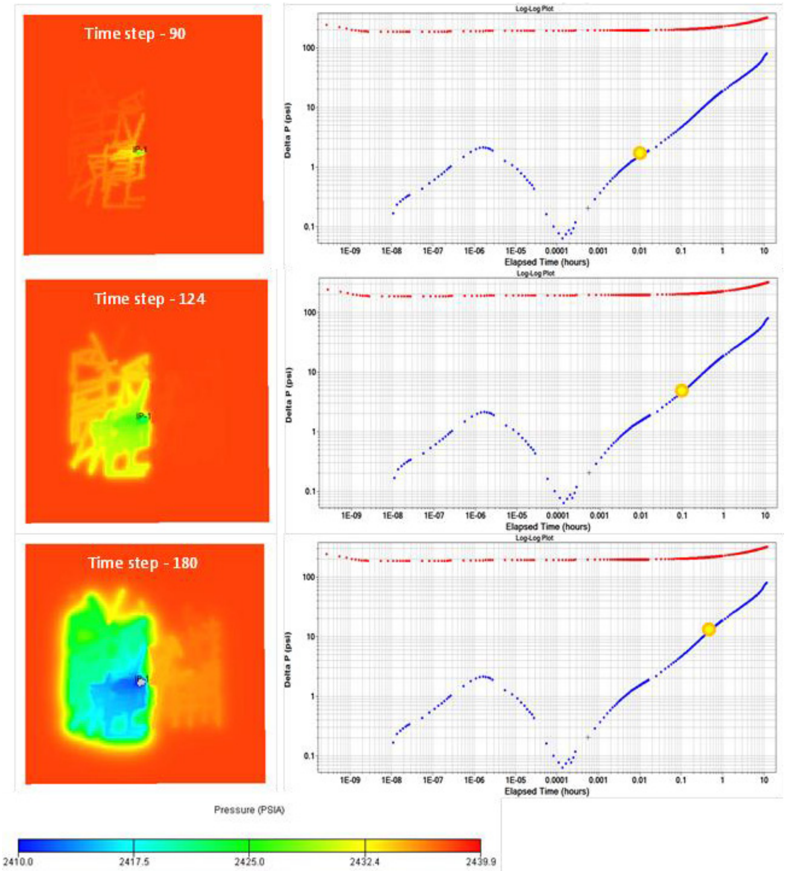

Figure 5: Time lapse pressure plots during a well test pressure build-up at various times identified by yellow dot on the derivative

Acknowledgements

Authors acknowledge the provision of Eclipse from Schlumberger and for Pan System from Weatherford for use in this research study. Kevin Bisdom is supported by Total.

References

Aljuboori, F., 2014, Geological Well Testing in a Fractured Carbonate Analogue, Unpubl MSc Thesis, 60p.

Bisdom, K., Bertotti, G., and Gauthier, B.D.M., 2014, Predicting Multi-scale Deformation and Fluid Flow Patterns in Folds Using 3D Outcrop Models and Mechanical Modelling, 76th EAGE Conference & Exhibition, Amsterdam RAI, The Netherlands, 16 – 19 June.

Corbett, P.W.M., Geiger, S., Borges, L., Garayev, A., and Valdez, C., 2012, The Third Porosity System: Understanding the role of hidden porosity in well test interpretation in carbonates, *Petroleum Geoscience*, v18, 73-81.

Delorme, M., Mota, R., Khvoenkova, N., Fourno, A., & Noetinger, B., 2014, A methodology to characterize fractured reservoirs constrained by statistical geological analysis and production: a real field case study.in Spence et al., (eds.) Advances in the Study of Fractured Reservoirs, Geol. Soc. Spec. Publ. 374, 273-288.

Geiger, S., and Matthäi, S., What can we learn from high-resolution numerical simulations of single- and multi-phase fluid flow in fractured outcrop analogues? Geological Society v.374, (2012), doi: 10.1144/SP374.8.

Spence, G.H., Redfern, A., Aguilera, Bevan, T.G., Cosgrove, J.W., Couples, G.,& J-M. Daniel, 2014, Advances in the Study of Fractured Reservoirs, Geol. Soc. Spec. Publ. 374, 425p