HYDRAULIC UNITS APPROACH CONDITIONED BY WELL TESTING FOR BETTER PERMEABILITY MODELLING IN A NORTH AFRICA OIL FIELD

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INTRODUCTION

Many of the petrophysical models used for simulation studies are based on the classical approach of cross plotting the logarithms of permeability versus porosity and then, by fitting a regression line on this plot, predicting the permeability through the reservoir rock (Fig. 1). This approach is critical when used to model permeable rocks, as it implies two misleading concepts. First, it considers the relationship between the logarithms of permeability versus porosity as linear, although it is mentioned in the literature that there is no theoretical basis to support this assumption. Secondly, using log porosities on this plot to predict the permeabilities would imply a scaling agreement between the macroscopic level (core plug) and the megascopic level (log data).

Discretizing the reservoir into units such as layers and blocks, and assigning values of all pertinent physical properties to these blocks will give a better agreement with the reservoir heterogeneity. The Hydraulic Unit concept (Amaefule *et al.*, 1993) was selected for subdividing the reservoir into distinct petrophysical types. Each distinct reservoir type has a unique Flow Zone Indicator (FZI) value; hence, an average permeability value can be predicted for each class and assigned in the model to the representative block or region (Fig 2). Amaefule's Hydraulic Units are a misnomer as they are merely subdivisions of the poro-perm data into petrophysical classes – whereas unit implies something with vertical and lateral extent. The approach expanded on in this paper addresses the modelling of the lateral extent of Hydraulic Units. A case study from a Triassic fluvial reservoir in North Africa is used to demonstrate this.

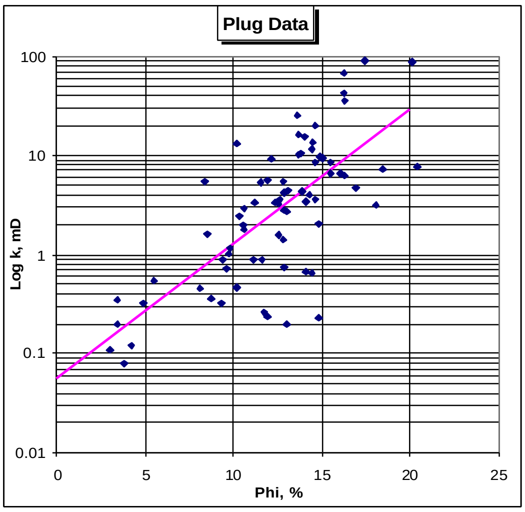

Fig. 1: Log k vs ϕ for the plug data

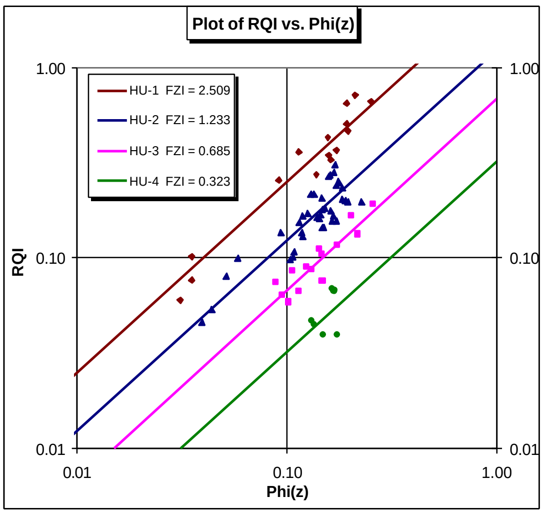

Fig. 2: hydraulic units in the North African reservoir

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Stochastic simulation with equiprobable realisations was accomplished to interpolate the three dimensions representative of the reservoir hydraulic units. Three models were constructed with different correlation lengths, (homogeneous, heterogeneous and very heterogeneous), in order to investigate the variability and continuity of the hydraulic units through a set of generated synthetic well test response, and matched against actual well test data. With this approach, we show how one of the geological models (the very heterogeneous) validated and calibrated with dynamic data and then transferred to fluid flow simulation to match the production history prior to generate a numerical well test.

STATIC CLASSIFICATION AND DYNAMIC VALIDATION

The value of this approach allows for more quantitative definition and mapping of the parts of the sand that are most important to reservoir behavior, and forms a realistic basis for definition of reservoir zonation to be used in the numerical simulation of reservoir performance. On the poro-perm plot (Fig. 3), one can obviously distinguish the quantitative clustering classification of the reservoir rock quality moving from poor quality unit at the bottom, up to the very good quality unit at the top.

Plotting the hydraulic unit-coded Lorenz Plot provided an excellent characterisation of the hydraulic units by their relative contribution to storage (porosity-thickness) and transmissibility (permeability-thickness) (Fig. 4). It is distinguished on this plot that approximately 70% of the flow (transmissibility) are dominated by HU1 that provides only 20% of the storativity in the reservoir.

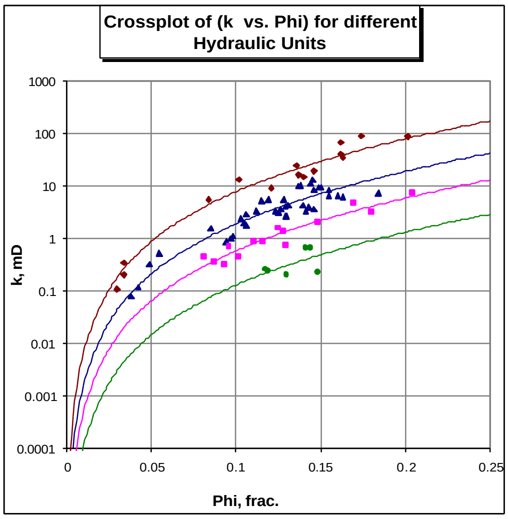


Fig. 3: Poro-perm plot showing hydraulic units

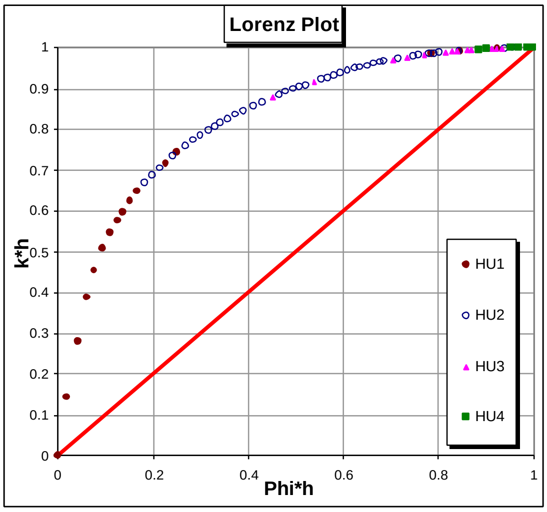


Fig. 4: Lorenz plot defining Transmissibility-dominated HU1 and Storage-dominated HU2, 3 and 4.

Flowing profile over the perforated intervals (Fig 5), confirmed that the location of a single HU (HU1 only in this case, in Fig. 4) controls the inflow profile and validates the geological model for this field, that the coarse grained material provides the highest permeability. In clastic reservoirs, the HUs are controlled by the depositional primary texture (grain size and sorting) (Corbett *et al.*, 2001).

STOCHASTIC SIMULATION

The aim of stochastic modelling is to produce numerical representations of a reservoir close enough to reality. The candidate realisation should have the same fluid flow characteristics as the true reservoir and should honour the past production history of the field. The fluid flow behaviour in the reservoir is a function of the flow rates and the pressure responses. This function depends on the distribution of the permeability and porosity throughout the field.

Porosity and permeability relationship are uniquely defined for each HU (A breakdown by lithofacies showed no clear relationship). Modelling at the scale of HU rather than lithofacies is key to assigning the correct physical data in a field simulation model. The HU is a smaller unit of homogeneity, requiring discrete modelling.

Hydraulic Units were considered as a property and distributed in the reservoir using pixel-based model to capture variation in location and geometry. Three models were built, in which the spatial continuity of the hydraulic units was the only uncertain parameter (Fig. 6). Those models are particularly used if a geological interpretation of the origin of the coarse-grained “patches” is not obvious, which is the case in this field.

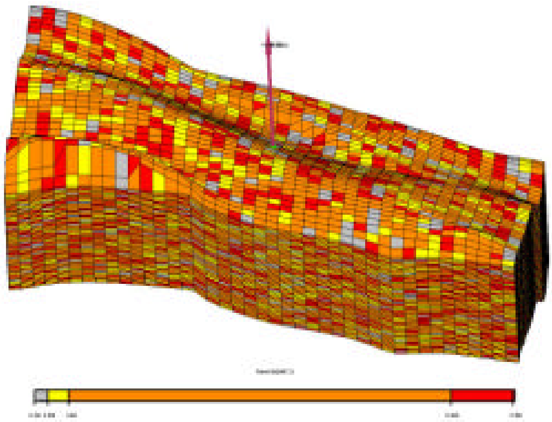
The geological model was transferred to the fluid flow simulation. Appropriate saturation curves, capillary pressure data, relative permeability and PVT data were assigned to each HU in the model. In order to make the model more realistic, the geological cube model was constrained by the local reservoir structure and isopach maps. The permeability was tuned slightly to meet good history match (Fig. 7) as no Klinkenberg corrections were applied to correct the lab data.

The goal is to generate numerical representations of the reservoir leading to the desired well test, the resulting image must also satisfy geological attributes. In this example, we show how we quickly gained a very good history match by applying the concept of the Hydraulic Unit within the modelling workflow.

CONCLUSIONS

- The hydraulic unit technique identifies the prevailing HUs in the reservoir using core data and various cluster analysis techniques.
- The reservoir heterogeneity profile and permeability distribution along the perforation was quantified and captured by the use of Lorenz Plot and the integrated inflow profile.
- Using the dynamic data (production logging) validated the hydraulic unit geological models.
- Three different models were built to investigate the lateral extent of the HUs around well bore. The very heterogeneous one is presented in this work and showed a good match with the historical performance of the reservoir.
- The results of the hydraulic unit determination provided the delineation of the regions that used for the simulation models.
- The fine scale HU definition at the well bore needs to be maintained in the scale-up procedure

Fig. 6: 3D representation from the fluid flow simulation of the permeability distribution for each hydraulic unit.



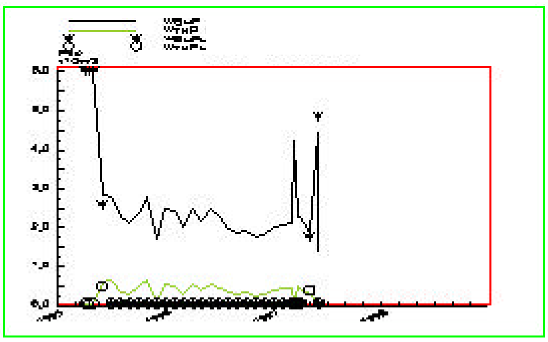


Fig. 7: The history match of the simulated hydraulic unit (heterogeneous case)

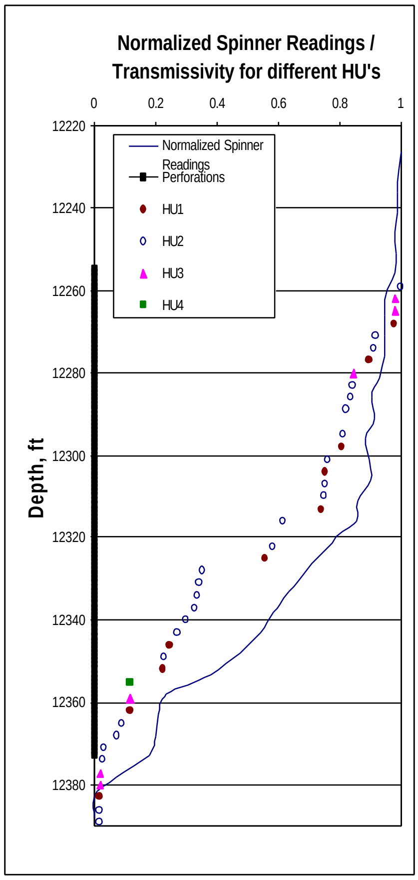


Fig. 5: HU against PLT showing how model flow is dominated by HU1.

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