Establishment of a Geological Fracture Model for Dual Porosity Simulations on the Ekofisk Field

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In order to construct a geologic fracture model for use in dual porosity simulation of the Ekofisk Field, all cored wells on the field were examined, and both lithological and fracture data were assembled. Fracture density distribution in the reservoir was mapped on the basis of estimated tectonic matrix block dimensions in the cored walls. Observed relationships between fracture density, lithology and structural positions formed the basis for statistical evaluation of logs in non-cored wells to assess the fracture density in areas outside the control of cored wells. Different logfacies types, defined by cluster analysis on log data, were quantified with respect to fracture density, and the tectonic fracture densities were predicted and mapped per reservoir layer. Equations for calculating fracture porosity and permeability were subsequently established, and the results contoured.

The geological fracture model was thereafter adjusted to well-test data, and the porosity and permeability for the stylolite fracture network was calculated separately and added to the tectonic fracture maps.

INTRODUCTION

Over the past 10 years there has been a recognition that fractured reservoirs cannot adequately be simulated by single porosity simulators, and complex dual porosity/dual permeability reservoir performance simulators have been developed. This, however, raised the need for input parameters to describe the fracture systems. The complexity of fracture origins, and the resulting variability in morphologies and distributions of natural fracture systems require unique quantitative geological data for any fractured reservoir modelling.

The Ekofisk Field is a dome shaped, fractured chalk reservoir located at 3200 m depth in the Central Graben of the North Sea. The field consists of two main reservoirs, the Tor Formation of Maastrichtian age and the Ekofisk Formation of Danian age. The two reservoirs are separated by a tight argillaceous layer.

As part of Norsk Hydro's reservoir modelling project of the Ekofisk Field, a fracture model based on geological data was developed. This chapter follows the development of this model and discusses the procedures used and results obtained, as well as precautions and assumptions involved in the work.

It is recognized that the numerical fracture model that was eventually adapted to the simulator will never reflect completely the considerable geological variability found in the Ekofisk fracture network. However, the study has shown that, using core and log data, a model can be developed that successfully matches the fracture permeability independently assessed from well test data. Critically, for reservoir simulation, the model provides fracture data in all layers throughout the reservoir.

CORE OBSERVATIONS AND CONCLUSIONS

Considerable effort was spent on core studies to provide a sound basis for the model. Cores from 13 wells with a total of 990 m of core were described in detail (Fig. 1), and both fracture systems and sedimentological facies were described.

Stratigraphic and structural distribution of fractures

In all wells two main fracture types with different stratigraphic and structural distributions occur, as illustrated in Fig. 2.

The tectonic fractures can be classified as subvertical, small-scale normal faults arranged in parallel and conjugate sets cutting through the stylolites. These fractures are seen...
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Stylolite fractures are closely associated with stylolites, forming vertical fracture planes usually normal to the stylolite surface and terminating against the tips of the stylolite teeth (Watts, 1983). They are rarely observed to cross or offset any stylolite surfaces. Their average vertical length is 10 cm and the spacing between the fractures is often less than 5 cm. They are generally not mineralized and they may represent highly permeable zones parallel to the stylolites, thus linking together the longer-spaced tectonic fractures.

The stylolite fractures are typically found in the Tor Formation, but in some downflank wells they also occur in the lower part of the Ekofisk Formation. In contrast, tectonic fractures are typically found in the Ekofisk Formation, but are also common in the upper Tor Formation, mainly in crestal wells or where the matrix porosity is high. Figure 3 shows schematically the distribution of the fracture types.

Whereas stylolite fractures in the Tor Formation seem to occur in all wells, independently of structural position, the presence of tectonic fractures appears to depend strongly on a structural control (the structural factor). In all layers, the tectonic fractures are most closely spaced in the crestal and fault-dominated areas, with spacing increasing markedly downflank.

Matrix block dimensions

A matrix block is defined in engineering terms as a volume of chalk matrix completely surrounded by open tectonic fractures that disrupt capillary continuity. In this study, fracture density was therefore expressed as the average size of matrix blocks, defined by height, width and length (Fig. 4).

The approach used was to measure two of these dimensions (block height and width), directly on the core, producing results as shown in Figs. 6 and 7. However, estimation of block sizes from cores was complicated by two factors: one is that approximately 60% of all tectonic fractures seem to terminate at fracture intersections, thus forming polygons of variable shapes and sizes rather than a geometrically well-defined pattern. The second is the fact that since the core width is a maximum of 10 cm, only a fraction of these matrix block polygons can actually be seen. Consequently, judgement had to be applied in averaging interval block sizes. The upper limits of block sizes feasible to define by core examination was determined to be approximately 50 cm. In general, the block sizes so defined represent the minimum block sizes within the given interval. However, when dynamic conditions are considered, the block sizes represent a minimum height of capillary continuity only in sequences of massive chalk with no stylolites, clay seams or other bed-parallel disruptions. Elsewhere, the stylolite spacings or the spacing...