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The Use of Unconventional Technology to Develop Zechstein Tight-Gas Reservoirs in the NE Netherlands

With NAM's maturing portfolio of (non-Groningen) gas fields in the NE Netherlands, the emphasis in the coming years will be on managing mature field life and developing more difficult fields such as tight Zechstein carbonate fields. A typical Zechstein gas field in the NE Netherlands usually consists of numerous poorly connected fault blocks and the reservoir is a tight carbonate, which has been deposited in a slope/basinal environment. Production shows largely varying individual well rates and where good productivity occurs, it is generally attributed to the presence of natural fracture networks. Zechstein reservoirs have been produced for many years mainly as a secondary target by perforating (vertical) wells when production from the underlying Carboniferous sandstone reservoirs had ceased. Other development options are generally uneconomic unless the implementation of unconventional technology increases the chance of successfully maturing the remaining scope volumes. Such unconventional technologies, which may help to predict, intersect and complete on fracture networks, are:

- Deterministic geomechanical fracture prediction models (using Poly3D) calibrated with dynamic reservoir performance to help to optimising well placement and forecast production.

- The employment of Coiled Tubing Under Balanced Drilling (CTUBD) technology to enable the drilling of horizontal well trajectories while mitigating massive losses (which historically prevented drilling past the first fracture encountered), maximizing the chance to intersect a fracture network, and minimizing impairment.

- Barefoot completions to ensure optimum connectivity between the well bore and intersected fractures.

Fracture Prediction

Indications for a fractured reservoir - where the rock matrix provides the storage capacity and fractures the permeability - are the presence of open fractures in cores and bore hole image logs, mudlosses while drilling, varying production rates, well test data and history matching. Fracture characterization (in terms of aperture, spacing, orientation and connectivity) from the scarcely available core and bore hole image data appears ambiguous and difficult (apart from fracture orientation) and the approach to upscale these properties to support a dynamic simulation has been discarded. Furthermore, simple field-wide fracture models (uniform, random, fault damage) failed the test against dynamic data, and indicate that the fracture distribution is neither uniform nor random, nor per se concentrated around faults.

To predict the fracture distribution, an alternative, deterministic, geomechanical fracture model was build using Poly3D, a boundary-element code that calculates the distortion of the regional stress field around larger, seismically visible, faults. The stress distribution is translated into a brittle failure (of the rock matrix) map indicating the areas with potential open fractures. These maps were then used to fill the dual-permeability grid of Shell's dynamic reservoir simulator. Dynamic simulation revealed that 70% of the wells can be history matched; better then any other model. Therefore, these geomechanical fracture models which are calibrated with dynamic reservoir performance can help optimizing well placement and provide a basis for forecasting production from the tight fractured ZEZ2C reservoir.

Coiled Tubing Under Balanced Drilling

The envisaged benefits of the application of CTUBD in tight fractured reservoirs are:

- Increased well productivity and ultimate recovery: Pressures in the fractured carbonate reservoirs can be below hydrostatic, consequently when a major fracture is intersected with conventional overbalanced drilling techniques, total losses occur and the TD of the well must often be called prematurely. CTUBD enables continuing drilling beyond the first intersected fracture system, intersecting additional fractures and completion of multiple targets. This significantly increases the connected reserves and well productivity. Additionally, CTUBD techniques are expected to have a positive effect on production from hair- or micro-fractures that are typically plugged off by filtercake when drilled with conventional drilling mud.

- Reservoir / fracture characterization while drilling: CTUBD enables immediate, in situ data gathering of the number of accessed fractures, fracture density and productivity as drilling progresses. This enables the testing and calibration of the predicted fracture distribution, which would not be possible using conventional drilling techniques. Hence, Poly3D fracture prediction and CTUBD are considered complementary technologies.

Well results

A two-well project in the Coevorden Zechstein field has recently been completed. The objectives were to trial the unconventional Poly3D & CTUBD technologies and develop sour gas reserves from undrained faultblocks at a depth of ca 3000 mss. The operations were amongst the most challenging undertaken by the industry to date (sour, deep, high pressure and temperature, high flow rate) and have pushed the technical limit for coiled tubing underbalanced drilling applications. The use of coiled tubing ensured a safe underbalanced operation during which multiple productive fractures were intersected without the mudlosses that have historically prohibited drilling to planned TD. Operational performance was good with a total of 1040 m of reservoir drilled in three separate lateral legs of which over 525 m was drilled by a single drilling bottomhole assembly. Gas flow rates with a PI of up to 60,000 m3/d per bar drawdown were measured while drilling, exceeding expectations. The rates progressively increased with the number of intersected fractures. A first estimate of the sustainability of the well capacity and the actual developed reserves will be made based on a production period of at least six weeks.

The well trials are encouraging and do justify to continue the use of geomechanical fracture prediction (calibrated with dynamic reservoir performance) in combination with coiled tubing underbalanced drilling. These complementary technologies appear critical for optimising well placement, forecast production and intersecting productive fractures in tight carbonates. Follow-up projects are currently being matured in other fractured carbonate fields in the NE-Netherlands.