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Fault Compartmentalization of a HP/HT Field

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SUMMARY

Fault compartmentalisation maps have been produced for two reservoir horizons for a field located on one of the deepest fault blocks in the Viking Graben. Mapped fault rock properties in conjunction with Mercury injection data were used to calculate maximum Hydrocarbon columns and associated threshold pressures to obtain a static fault seal model. In general mapped fault rock properties indicate a high lateral and vertical variability. Key uncertainties comprise the structural interpretation and the relation between Mercury injection pressure and SGR. Given the presence of different Hydrocarbons, interfacial tension is expected to vary within the field significantly, thus giving rise to different column heights and threshold pressures for the same fault rock type. Thus, the structural compartmentalisation is superimposed by an HC property compartmentalisation and their spatial distribution is not expected to be the same. Given the HP/HT nature of the field, even low SGR fault rocks can sustain several 10's of meters of HC columns. The compartmentalisation maps in conjunction with the present Gas Water Contacts, the Gas Oil Ratio distribution, as well as the resulting communication paths, provide strong support for an upside potential for some compartments surrounding the discovery wells.

The field is located on the Norwegian Continental shelf on one of the deepest fault blocks of the Viking Graben. The field exploits a Jurassic reservoir, where wells have documented HP/HT conditions. The interpreted fault pattern is characterised by major N-S trending normal faults, potentially inherited from the Permo-Triassic rift event; and by minor E-W trending faults leading to an extensive potential fault compartmentalisation of the field. Condensate has been proven in the NE of the field, whereas Gas has been discovered in the SW. Current interpretation of the Gas Oil Ratio calls for a communication between these two regions.

The five drilled wells show all signs of compartmentalization; one dry well, different hydrocarbon composition and different gas gradients. Thus, understanding structural compartmentalization is crucial both for calculating reserves and for planning the development of the field. Fault transmissibility has been calculated for reservoir simulation purposes using the Shale Gouge Ratio and Shale Smear Factor algorithms in the RMS fault seal module, which results in a fairly open model during production. To better understand the distribution of the controlling fault rock types and to better match the current fault seal model with compartmentalisation observations, fault compartmentalisation maps showing the distribution of the most open fault rock were produced for the upper and lower part of the reservoir assumed to represent independent pressure cells. The latter are separated by a thick shale sequence. The resulting most open fault rock map in conjunction with the GWC and GOR distribution, provided key constraints to understand across fault and thus across field communication.

An essential element of a fault-seal analysis is to calibrate the fault-seal attribute, i.e. the Shale Gouge Ratio with laboratory derived measurements of the fault rock properties taken as a proxy for fault-zone composition and compare those with faults where the sealing behaviour can be demonstrated using pressure data from wells on either side of the fault (Bretan et al. 2003). The basis for such a calibration is the observation that faults represent membrane or capillary seals. Leakage of hydrocarbons through a water-wet fault zone occurs when the buoyancy pressure exceeds the pressure required for hydrocarbons to enter and pass through the largest interconnected pore throat in the seal, referred to as displacement or capillary entry pressure (e.g., Smith 1966, Schowalter, 1979, Bretan et al. 2003).

Following this theoretical background a fault seal study including the mapping of the most open fault rock was carried out. In a first step threshold pressure measurements of Mercury into fault rocks derived from cores were recalculated to mimic reservoir conditions. Given the presence of two different Hydrocarbon types in the field a range of interfacial tensions and their effect on the resulting threshold pressures and associated maximum Hydrocarbon columns was explored. Our results suggest that the relation between the measured Mercury entry pressure and the observed SGR has the strongest, the considered interfacial tension a strong and the Hydrocarbon density the least bearing on the resulting threshold pressures and associated Hydrocarbon columns. This implies that the same mapped fault rock may sustain different Hydrocarbon columns depending on the Hydrocarbon type present. Thus, the structural compartmentalisation is superimposed by a Hydrocarbon compartmentalisation and their spatial distributions are not anticipated to match. Furthermore, differences in GWC shall be expected across the field.

Our results indicate that fault rock properties show a high along strike and in dip variability. Even the most open fault rock, i.e. SGR of 10% can sustain Hydrocarbon columns up to several 10`s of meters. This might result from either one or most likely a combination of the following processes: Quartz cementation/dissolution, compaction and cataclasis. Most importantly, this study provided strong support for an upside potential for compartments surrounding a discovery.

The calibration show that the mapped most open fault rock and the assigned threshold pressures derived from the calibration study are in good agreement with the well observations, but that a detailed calibration is difficult due to uncertainty in interfacial tension. It shall however be emphasized that these most open fault rock maps represent static reservoir conditions. During production, pressure depletion may cause threshold pressures to be exceeded and allow across fault fluid flow.

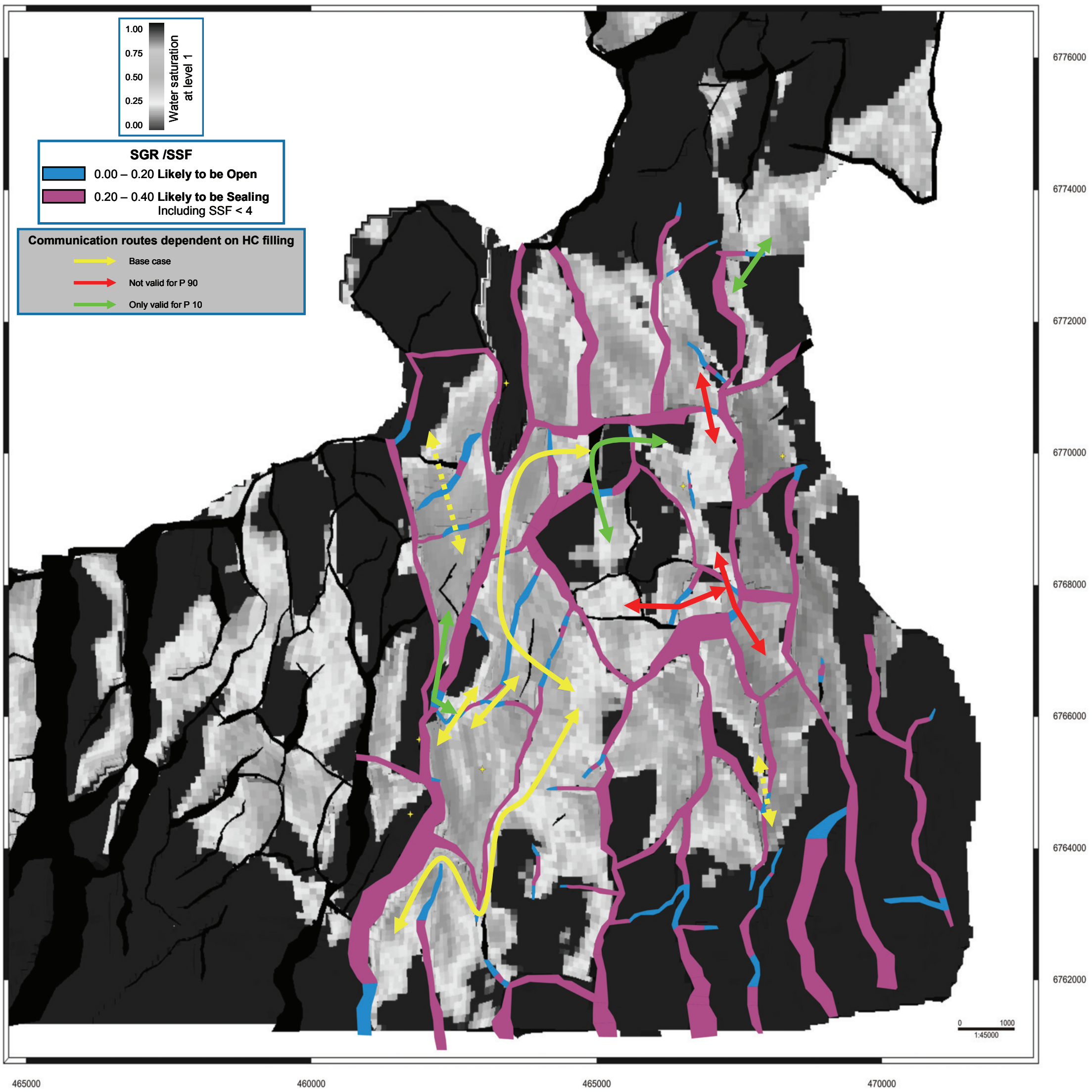

Figure 1 *Most open fault rock map, where an SGR > 0.20 is considered sealing. Base Case for GWC is shown. Arrows indicate potential communication routes depending on the amount of filling.*

References

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