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Characterization of Fluid Connectivity in Reservoirs using Strontium Isotopes

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Routine measurements of formation pressure while drilling reservoirs can indicate the presence of internal barriers to vertical fluid movement when there is a sudden shift in the pressure data. However, pinpointing the location of a barrier is often not possible since the density of pressure measurements is low and irregular. The aim of this contribution is to show how the Strontium isotopic system can help characterize the fluid connectivity and pinpoint the precise location of low permeability barriers in reservoir units and sedimentary sequences. As an example, we use a 25 m thick interval within the Middle Jurassic Hugin reservoir unit of the Langfjellet oil discovery on the Norwegian Continental Shelf. The location of the barrier is constrained by the upper and lower pressure measurements and could correspond to any of the several layers of silt, shale or coal layers in this interval. In this study, we collected every 2-4 m a total of 40 samples from a 110 m long cored section of a technical side-track well over the available. Each sample was prepared and analyzed using the SrRSA method (Strontium Residual Salt Analysis), which measures the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio in salt residue that precipitated in the pore space after the core dried out. The $^{87}\text{Sr}/^{86}\text{Sr}$ is a natural tracer because the ratio is not affected by mass fractionation. The $^{87}\text{Sr}/^{86}\text{Sr}$ in rocks is mostly acquired by water-rock interactions during diagenesis and evolves through mixing and equilibration of different water bodies, unless low-permeability barriers prevent equilibration. Therefore, the SrRSA patterns observed in the well represent a 1D snapshot of the fluid dynamics at the time of oil filling, which is a frozen image of competing equilibrium vs disequilibrium conditions. The SrRSA data follow a smooth trend of content values at 0.713 and display a sudden jump to lighter 0.709 values near the top of the 25 m thick interval that suggests the presence of a potential barrier. The lithological core log shows that the SrRSA step change corresponds to a coal-shale unit, which is interpreted to represent the barrier. The SrRSA data further demonstrate the reservoir unit at Langfjellet does not contain any other barriers to fluid flow, since pressure equilibration could have masked a possible compartmentalization. This study shows that the SrRSA method is a powerful tool that should be routinely applied for the characterization of fluid connectivity of storage units.