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Production Induced Faulting and Fault Leakage in Normal Faulting Regions: Examples from the North Sea and Gulf of Mexico

The potential fluid injection to initiate slip on faults in the vicinity of oil and gas reservoirs is well known and easily explained in the terms of locally increased pore pressures reducing the effective normal stress on pre-existing faults. In this study, we demonstrate through both theory and field examples that the poroelastic stress changes accompanying hydrocarbon production can reactivate slip on pre-existing, reservoir-bounding normal faults and thus promote fault leakage. We utilize in situ stress and pore pressure data from the Valhall and Ekofisk fields in the central North Sea to demonstrate that the pre-production state of stress in the crests of the structures was consistent with an active normal faulting environment. Analysis of microearthquake data from the Valhall field confirms that normal faulting in the crest of the structure is an active process which is likely largely responsible for the extensive gas leakage known to be occurring there. We further demonstrate that on the flanks of both the Valhall and Ekofisk structures, that the poroelastic stress path associated with production-related changes in pore pressure are such that normal faulting spreads out into the flanks of the structures, likely promoting leakage there, even though the faults on the flanks were initially inactive. In the Gulf of Mexico, we utilize data from the South Eugene Island 354 and 330 fields to demonstrate that similar processes may be occurring in fault bounded reservoirs there. Finally, we demonstrate that if initial stress and pore pressure conditions are known in a reservoir, it is possible to estimate the likelihood for production-induced normal faulting to occur if the stress path is measured directly from field observations made over time or estimated from poroelastic theory.