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The subsurface impact of hydraulic fracturing in shales- Perspectives from the well and reservoir

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It has been identified that the main risks of subsurface shale gas operations in the U.S.A. and Canada are associated with (1) drilling and well integrity, (2) hydraulic fracturing, and (3) induced seismicity. Although it is unlikely that hydraulic fracturing operations result in direct pathways of enhanced migration between stimulated fracture disturbed rock volume and shallow aquifers, operations may jeopardize well integrity or induce seismicity. From the well perspective, it is often assumed that fluid injection leads to the initiation of tensile (mode I) fractures at different perforation intervals along the horizontal sections of shale gas wells if pore pressure exceeds the minimum principal stress. From the reservoir perspective, rise in pore pressure resulting from fluid injection may lead to initiation of tensile fractures, reactivation of shear (mode II) fractures if the criterion for failure in shear is exceeded, or combinations of different fracturing modes.

In this study, we compare tensile fracturing simulations using conventional well-based models with shear fracturing simulations using a fractured shale model with characteristic fault populations. In the fractured shale model, stimulated permeability is described by an analytical model that incorporates populations of reactivated faults and that combines 3D permeability tensors for layered shale matrix, damage zone and fault core. Well-based models applied to wells crosscutting the Posidonia Shale Formation are compared to generic fractured shale models, and fractured shale models are compared to micro-seismic data from the Marcellus Shale. Focus is on comparing the spatial distribution of permeability, stimulated reservoir volume and seismicity, and on differences in fracture initiation pressure and fracture orientation for tensile and shear fracturing end-members.

It is shown that incorporation of fault populations (for example resulting from analysis of 3D seismics or outcrops) in hydraulic fracturing models provides better constraints on well pressures, stimulated fracture disturbed volume and induced seismicity. Thereby, it helps assessing the subsurface impact of hydraulic fracturing in shales and mitigating risks associated with loss of loss of well integrity, loss of fracture containment, and induced seismicity.