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Hydraulic imaging of faults and fractures using a predictive statistical reservoir model

I.G. Main (1,3), L. Li (1,3) and K.J. Heffer (2,3)

(1) University of Edinburgh, School of GeoSciences, Edinburgh, UK (ian.main@ed.ac.uk), (2) Heriot-Watt University, Institute of Petroleum Engineering, Edinburgh, UK. (3) Edinburgh Collaborative of Subsurface Science and Engineering (ECOSSE), Edinburgh, UK.

Faults and fractures play a key role in controlling fluid flow in oilfields. Normally they are imaged by geophysical techniques (notably surface seismic and borehole geophysics) and then their effect on hydrocarbon production is determined by running physical simulations and comparing the output against fluid flow rates observed at producer wells. Here we present a new method for direct imaging of the effect of faults and fractures using solely hydraulic data. First we invert for a statistical reservoir model, based on monthly time series for flow rate measured at injectors and producers for a North Sea oilfield. The result is a parsimonious regression model for the minority of well pairs that are significantly correlated. The vectors connecting the significantly-correlated well pair align with the modern day stress field, and have a correlation (frequency-length) function that decays as a power-law, implying long range correlations. Both are quantitatively consistent with a critical, or near-critical, response to poro-elastic stress perturbations in independent numerical simulations of the same oilfield. A plot of the first principal component of the regression matrix aligns remarkably well with the pattern of macroscopic faulting in the reservoir, both in time-slice and time-lapse mode. The results predict the trend of 'future' data (i.e. data not used to condition the model) very well within quantifiable uncertainties.