Geophysical Research Abstracts
Vol. 17, EGU2015-11838-1, 2015
EGU General Assembly 2015

The Derivation of Fault Volumetric Properties from 3D Trace Maps Using Outcrop Constrained Discrete Fracture Network Models

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Fault systems are important structural elements within many petroleum reservoirs, acting as potential conduits, baffles or barriers to hydrocarbon migration. Large, seismic-scale faults often serve as reservoir bounding seals, forming structural traps which have proved to be prolific plays in many petroleum provinces. Though inconspicuous within most seismic datasets, smaller subsidiary faults, commonly within the damage zones of parent structures, may also play an important role. These smaller faults typically form narrow, tabular low permeability zones which serve to compartmentalize the reservoir, negatively impacting upon hydrocarbon recovery.
Though considerable improvements have been made in the visualization field to reservoir-scale fault systems with the advent of 3D seismic surveys, the occlusion of smaller scale faults in such datasets is a source of significant uncertainty during prospect evaluation. The limited capacity of conventional subsurface datasets to probe the spatial distribution of these smaller scale faults has given rise to a large number of outcrop based studies, allowing their intensity, connectivity and size distributions to be explored in detail. Whilst these studies have yielded an improved theoretical understanding of the style and distribution of sub-seismic scale faults, the ability to transform observations from outcrop to quantities that are relatable to reservoir volumes remains elusive. These issues arise from the fact that outcrops essentially offer a pseudo-3D window into the rock volume, making the extrapolation of surficial fault properties such as areal density (fracture length per unit area: P21), to equivalent volumetric measures (i.e. fracture area per unit volume: P32) applicable to fracture modelling extremely challenging.
Here, we demonstrate an approach which harnesses advances in the extraction of 3D trace maps from surface reconstructions using calibrated image sequences, in combination with a novel semi-deterministic, outcrop constrained discrete fracture network modeling code to derive volumetric fault intensity measures (fault area per unit volume / fault volume per unit volume). Producing per-vertex measures of volumetric intensity; our method captures the spatial variability in 3D fault density across a surveyed outcrop, enabling first order controls to be probed. We demonstrate our approach on pervasively faulted exposures of a Permian aged reservoir analogue from the Vale of Eden Basin, UK.