Relationship Between Folding and Fracturing in Outcrop-Scale Reservoir Analogues

Pearce, Mark A.[1]; Jones, Richard [1]; Smith, Steven [2]; McCaffrey, Ken J.[3] (1) Geospatial Research Ltd., University of Durham, Durham, United Kingdom. (2) Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy. (3) Dept. of Earth Sciences, University of Durham, Durham, United Kingdom.

Spatial variations in fracture density and orientation affect the permeability and flow anisotropy in reservoir rocks. Prediction of fluid flow properties, modified by fracturing at a sub-seismic scale, is an important step in creating a realistic reservoir model. These predictions can be validated using outcrop scale structures to correlate fracturing with geometric features such as fold curvature. Curvature has sometimes been used as a proxy for strain because it describes deviation from an initially planar surface. Numerical models of folding show stress concentrations at the hinges of developing folds. The orientations of resultant fractures are controlled by the stress distribution, in turn controlled by the fold orientation. Extremes of curvature in 3-D potentially provide a metric for the magnitude and orientation of the fracturing.

We use terrestrial laser scanning (lidar) to acquire a digital elevation model for three examples of periclines (four-way closures), where exposed single bedding surfaces allow a full 3D survey of fold geometry. Principle curvatures are calculated from the smoothed, filtered point clouds. Fracture densities and trace orientations are calculated and these data plotted onto 3D surfaces derived from the triangulated point cloud data. This novel use of precisely georeferenced data allows the spatial variation of surface and fracture attributes to be examined and compared for entire folds with much higher resolution than previously possible.

The results of this study show that one of the folds has maximum curvature in excess of 0.1 m^{-1} that correlates with increased fracture density around the hinge zone. The other two folds have a significant amount of fracturing, but neither shows a spatial correlation between curvature and fracture density. One fold does show an increase in hinge parallel fractures around the hinge zone. In this case the limbs have high fracture densities which are not related to curvature whilst the hinge is fractured during folding. This study shows that whilst curvature is a proxy for strain, it is not always a good proxy for fracture density - in our study there is no reliable systematic link. Many rocks have fracture densities inherited from early in their strain history and the densities are not necessarily modified by folding. However, detailed investigation of appropriate field analogues provides limits to the values of fracturing and anisotropy that can be expected in the sub-surface.