3-D Fracture Patterns in Outcropping Reservoir-Scale Anticline: New Acquisition Methods and Results from the Tata Anticline (Morocco)

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Natural fractures are common in anticlines and control physical properties of tight sandstones or carbonate reservoirs (e.g. Miocene Asmari reservoirs, Iran). General knowledge and commercial software packages often assume that fractures are caused by fiber stresses associated with folding and, consequently, that fractures are parallel to the fold axis and their intensity controlled by fold curvature. In the vertical dimension, it is thought that fracture spacing is directly proportional to the thickness of sedimentary layers. These models are unsatisfactory as they neglect i) the difference in fracture patterns generated by different folding processes, ii) the importance of regional stress fields, and iii) the 3D organization of fractures. Outcrop analogs have been used to provide answers to these issues but the resulting data sets are incomplete.

As an outcropping analog we use the Tata anticline (Morocco). The Tata anticline is exposed for an across-strike width of >400m and a length >1km. The folded succession is 30m thick and composed of Devonian sandstones with bed thicknesses from 0.2to 2m. The dip of the flanks is <10degrees. To overcome known shortcomings of conventional data acquisition methods and acquire full fracture data on the Tata anticline we have made developed new techniques. To analyse fractures on the back of the anticline we use a Helium balloon. The efficient recording of fracture data on vertical outcrops was done with DigiFract, an innovative implementation within an existing GIS that offers custom fracture acquisition procedures. Fractures in the Tata anticline are organized in three sets. A first set includes fractures parallel to the fold axis. They have spacing distances in the order of 0.2-0.3m and are typically longer than the outcrop (>1km). In vertical outcrops, fractures of the first set cross the entire stratigraphy which, therefore, behaves as a single mechanical unit. Smaller fractures are observed in the outer and inner parts of the anticline. The 2nd set is composed of joints perpendicular to the fold axis. They show spacing of 1-2m. Fractures of set 2 are generally longer than the outcrop. The 3rd set is composed of closely spaced fractures generally <1m long bounded by fractures parallel to the fold axis. The orientation of the fractures is oblique to the fold axis. The difference between the characteristics of the fracture sets has implications for drilling strategies in fractured anticlinal reservoirs.