# Characterization of Fracture Networks: Examples from Outcrop Analogues of the Late Jurassic Jubaila Formation

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## Abstract

Objectives
Fracture characterization is a key methodology for reducing uncertainty in reservoir characterization. Natural fractures have a significant impact on subsurface permeability and productivity, and consequently on the recovery factor. The origin of fractures is mainly related to regional tectonic events that lead to the formation of similar fracture patterns over large areas. The objective of this study is to characterize the fracture distribution in outcrop analogues of the late Jurassic Jubaila Formation using a drone-based Digital Outcrop Model (DOM). Digital photogrammetry enables complete 3D observation of fracture geometries. This approach overcomes common limitations in subsurface fracture studies, which are expensive and limited in resolution and spatial coverage (e.g. observation from well data). In addition, DOM application avoids limitations often encountered in field studies, such as surveying km-scale areas and inaccessible areas. Digital Outcrop Models provide a robust representation of fracture networks at inter-well scale. The methodology was tested and validated in Jurassic outcrops of central Saudi Arabia. We are able to characterize fracture network by describing: (1) fracture orientation, (2) fracture sets, and (3) the timing of formation, considering the main tectonic deformation events affecting the eastern part of the Arabian Peninsula since the Jurassic.

Procedures
We applied drone-based digital photogrammetry to reconstruct a Digital Outcrop Model for the Late Jurassic Jubaila Formation near Howta Bani Tamim, Saudi Arabia. The Late Jurassic carbonate succession experienced into two major tectonic deformation events: (1) The late Cretaceous Alpine I event, characterized by NW-SE oriented maximum horizontal stress, and (2) the Oligocene to Miocene Alpine II event, characterized by NE-SW orientated maximum horizontal stress. These two major events significantly affected tectonic deformation on a regional scale. We mapped the visible fractures on the 3D DOM-constrained high-fidelity fracture network model and defined the following parameters: dip, dip direction and strike angle, size, spatial distribution (e.g., fracture density and intensity) and cross-cutting relationships. In addition, from the analysis of 25 km2 high-resolution orthorectified satellite images, it was possible to map large-scale tectonic features in the area of interest. In this way, it was possible to characterize the orientation of lineaments at different scales.

Results
Thousands of fractures mapped in the study area allow the interpretation of three fracture sets, oriented E-W, NNE-SSW and NW-SE. The preliminary results show an average fracture dimension in DOMs of 1.4 m (max. 12 m, min. 0.07 m). Based on the analysis of satellite images it was possible to define two fracture sets oriented NE-SW and NW-SE, with few lineaments oriented E-W.

## Conclusions

Considering the orientation of fracture sets and the geological history of the Late Jurassic Jubaila Formation, it was possible to relate the formation of the NW-SW oriented fracture set to the Alpine I (E-W) and Alpine II (NNE- SSW) deformation events. Moreover, analysis of satellite images revealed similar trends at larger scale. Results of this study show that outcrop observations can be transferred to subsurface reservoirs and reduce uncertainties in their interpretation and prediction.