Evolution of a Multi-scale Fracture System as a Result of Stress Re-orientation, Cambrian Umm Ishrin Formation, Jordan

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Natural fracture networks are the result of the interaction of a 3-D stress system with the rock properties, both of which change through time. This research focuses on an area where the effects of stress re-orientation can be studied in the field. The highly fractured sandstones of the Cambrian Umm Ishrin Formation in Jordan exhibit excellent “near 3-D” exposures, and they represent a good reservoir analogue because of their rock properties (e.g. mineralogy, porosity, permeability and heterogeneity). Multiple phases of tectonic stresses have occurred since deposition of these sandstones, the last one of which is the stress system associated with the Dead Sea Transform (DST). Several stages of Gondwanan break-up during the Paleozoic and Mesozoic, collision of Africa and Eurasia and activation of the DST in the Tertiary generated and modified the developing fracture system. This study aims to unravel the evolution of the fracture network as a result of stress re-orientation during these tectonic phases and how this might affect important fluid flow properties in the fractured rocks.

A data set of over 27,000 fractures has been acquired in a GIS-environment from high-resolution satellite imagery and field data, using a multi-scale measurement approach. Two dominant fracture sets are identified across the study area and their length and spacing characteristics are found to show self-similar behavior over several orders of magnitude. The fracture system shows an organisation into regional fracture domains that are bounded by major lineaments such as fracture corridors. Based on a detailed study of the lithofacies and the mechanical stratigraphy, the relative timing of the different fracture orientations is investigated and tentatively related to the tectonic phases. Re-orientations of the stress system are thought to have affected pre-existing fractures in a variety of ways, sometimes changing them fundamentally. For example, extensional fractures may become entirely closed and cemented due to compressional stresses. It is posited though that the majority of the strain resulting from stress re-orientation is compensated in the major lineaments surrounding the fracture domains. These corridors can develop into major fluid flow highways through repeated reactivation under various stress regimes, and the fracture system they encase then acts as feeder for the flow from matrix blocks into the major conduits.