Geophysical Research Abstracts,
Vol. 11, EGU2009-5252, 2009
EGU General Assembly 2009

From Fractures to Flow, a Field-based Quantitative Analysis of an Outcropping Reservoir

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A large scientific interest has risen in the last decade on the characterization of carbonates' mechanical and petrophysical properties, as well as of the deformation mechanisms they are subjected to at shallow crustal levels. On this regard, we take advantage of an exposed hydrocarbon-bearing, fractured carbonate reservoir to address the role played by fractures present within fault damage zones on fluid flow. The study area is located along the northern termination of the Majella anticline, in central Italy, within a quarry originally excavated by the ancient Romans. There, hydrocarbons in the form of tar residues are present within two high-angle, oblique normal faults and in the porous carbonate beds flanking the faults.

After having documented the faulting processes and the mechanisms of carbonate deformation (Agosta et al., 2009), in this presentation we focus on the relation between the individual fracture characteristics (typology, length, spacing, aperture, orientation, connectivity, and distance from slip surfaces) and tar distribution. This is accomplished by analyzing data obtained from 1D scan lines measurements carried out along the quarry's vertical outcrops. Within the fault damage zones, most scan lines were oriented perpendicular to the main fracture sets, while a few others perpendicular to smaller faults.

We measured the attitude, length, distance from arbitrary points of the scan lines, aperture, content, and abutting relations of the tips of 1.148 fractures, 620 of which were tar-free whereas 528 contained tar residues. Data obtained from scan lines oriented perpendicular to the main fracture sets are used to investigate the relation between individual fracture characteristics (spacing, length, aperture, and orientation) and tar infilling. Data gathered from scan lines oriented perpendicular to small faults allow us to study the relation percentage of hydrocarbons in fractures with respect to fracture distance from slip surfaces. This is done separately for fractures in the fault hanging walls and fault footwalls.

After data computation, we discuss the individual relations among the different fracture characteristics and tar distribution in terms of fracture anisotropy within the deformed carbonates, and assess the control exerted by the local stress state on fracture porosity and, hence, on hydrocarbon migration. Then, we characterize the cumulative length and spacing distribution laws of individual fractures and sheared fractures present in either undeformed carbonate host rocks (background deformation) or faulted carbonates (fault-related deformation), and infer the local stress state during deformation.

Our data and observations are consistent with the following conclusions: (i) at a large scale, hydrocarbons are present primarily within releasing jogs of left-stepping normal faults characterized by minor component of left-lateral slip (ii) at smaller scales, the structural position of small and medium faults crosscutting the carbonate damage zones plays a role for hydrocarbon migration as well; (iii) fracture length and spacing data do not show any relation between with tar distribution; (iv) fracture aperture data suggest the possible control exerted by the stress state conditions on fracture aperture and, hence, on hydrocarbon flow; and (v) the fracture arrays showing a pronounced anisotropy seem to focus hydrocarbon migration.

References

Agosta F., Alessandroni M., Tondi E., Aydin A., 2009. Oblique normal faulting along the northern edge of the Majella anticline, central Italy: inferences on hydrocarbon migration and accumulation. Journal of Structural Geology, in press.