Analysis of the Structural Style and Fracture Distribution of the Agdagh Anticline in Southern Kurdistan, Iraq
A model for fractured Carbonate Reservoirs

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The Agdagh Anticline is a large northwest to southeast trending anticline located approximately 40 km. to the southwest of the city of Sulaymaniyah in the Kurdish region of Iraq. The structure has a surface expression that extends for over 65 kilometres in the strike direction and is approximately 10 kilometres wide. The larger structure is made up of two en echelon folds that trend parallel to each other and are separated by a minor syncline. The eastern fold is the subject of this investigation (Figure 1).

The Agdagh Structure is a foreland verging anticline that formed as a result of motion along a foreland directed deep detachment. The overlying Tertiary aged section was folded and brought to surface where it now lies as a well exposed series of outcrops. The fold has an asymmetric style with a near vertical forelimb, an over-thickened hinge and a relatively intact gently dipping backlimb. The section has a shallow regional detachment in the basal Miocene section (Fars Evaporite) that has been incorporated into the fold but also structurally dislocates minor folds in the overlying predominantly siliciclastic section from the main fold developed within the thick Eo-Oligocene carbonate strata that makes up the bulk of the surface expression of the fold (Figure 2).

The excellent three dimensional outcrop exposures of the fold allow for the study of the fracture systems developed around the fold. In the process of folding, the strata were fractured and an intense fracture distribution was developed across the entire structure. Fracture intensity is greatest within the hinge of the fold (Figure 3). The forelimb of the fold is also strongly fractured although to a lesser degree than the hinge. The backlimb of the fold also has fracture systems developed but to a much lesser extent than either the hinge or the forelimb.

High resolution satellite imagery was also used to aid in the fracture analysis. One of the difficulties in fracture analysis is to develop a method that quantifies the fracture intensity and minimizes the subjectivity often associated with fracture outcrop studies. A new practical statistical method using the satellite imagery and outcrop exposures has been developed to aid in the fracture analysis. The analysis is dependent on the recognition that the position of fractures forms a spatial series that can be readily analyzed using spatial frequency analytical tools.

A series of summing algorithms can convert fracture occurrence measured along scan lines into a spatial waveform that can then be analyzed with Fourier transforms. The dominant frequencies and the corresponding amplitudes can then be compared across the fold to give a quantitative estimate of the fracture intensity at different structural positions around the fold.

Similarly, the fracture intensity within different stratigraphic units may also be compared and a stratigraphy based on fracture distribution and intensity can be developed.

In the backlimb of the fold the fracture intensity of the Oligocene Jeribe Fm. is four times greater than the overlying Euphrates Fm. The fracture intensity of the front limb of the fold is over three times greater than the backlimb. In the backlimb of the fold the dominant spatial frequency for fracture development in the Jeribe Fm. is 0.005 m^{-1} with another fracture system overprinting at 0.008 m^{-1}. This suggests that from a statistical view one should anticipate a significant fracture swarm every 200 metres overprinted by another lesser system every 125 metres (Figure 4). Using the same approach the fracture system on the front limb has a dominant frequency that equates to a fracture swarm occurring every 30 metres, a substantially greater fracture saturation.

These types of results will aid in the design of lateral well paths into fractured reservoirs as the orientation and distance to fracture swarms is statistically determined using this approach. Risk factors such as the likelihood of vertical communication between different stratigraphic units can be estimated. This approach when calibrated with the test results from the equivalent subsurface reservoirs, will allow for the determination of the effects of fractures and the relationship between the matrix permeability system and fracture permeability system of the reservoir.

Figure 1: Location of the Agdagh Structure approximately 40 kms. south of Sulaymaniyah in the semi-autonomous region of Kurdistan, northern Iraq.

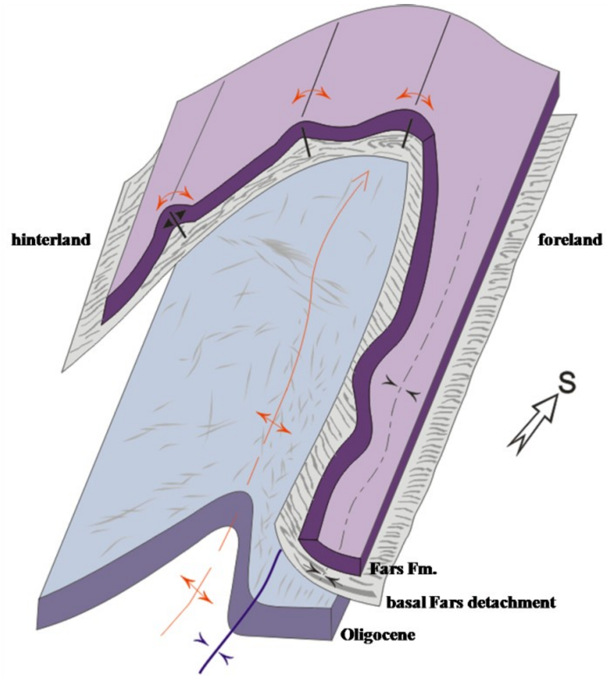

Figure 2: 3D Schematic of the Agdagh Anticline looking to the southeast. The fold has a foreland verging asymmetric style with a vertical forelimb, over-thickened hinge and stratigraphically intact backlimb.

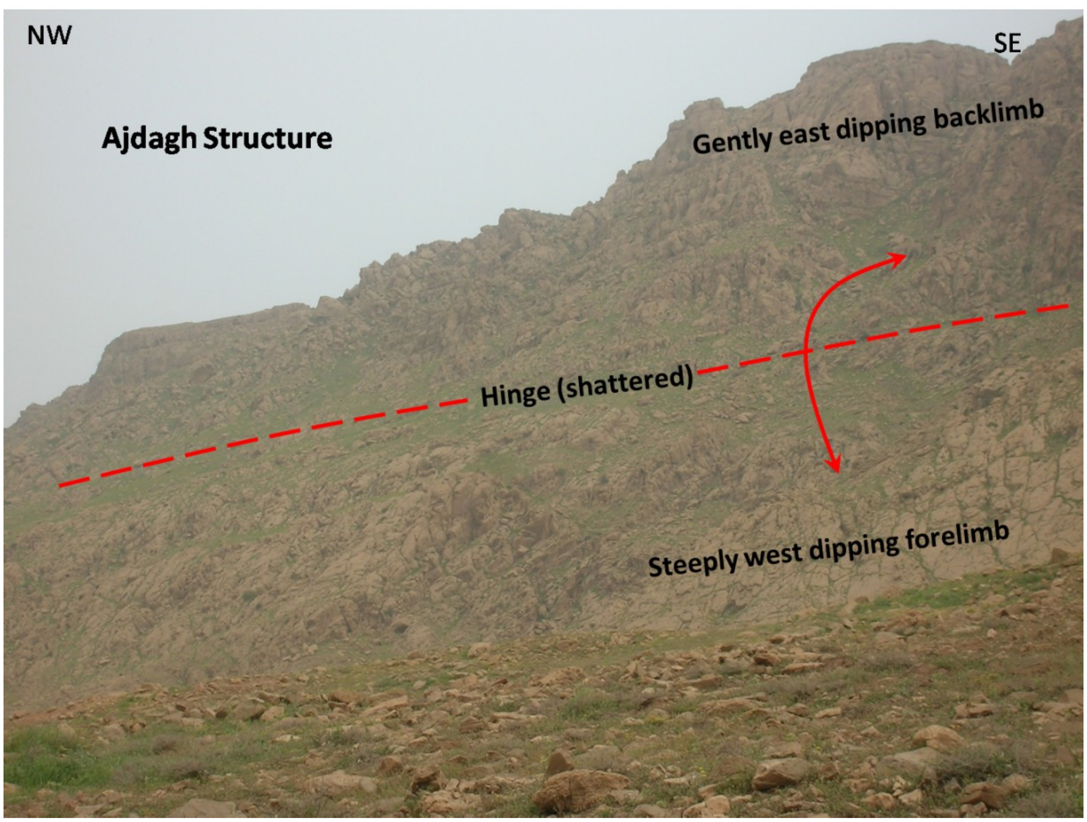

Figure 3: View of the relationship between the forelimb and the hinge of the Agdagh Anticline.

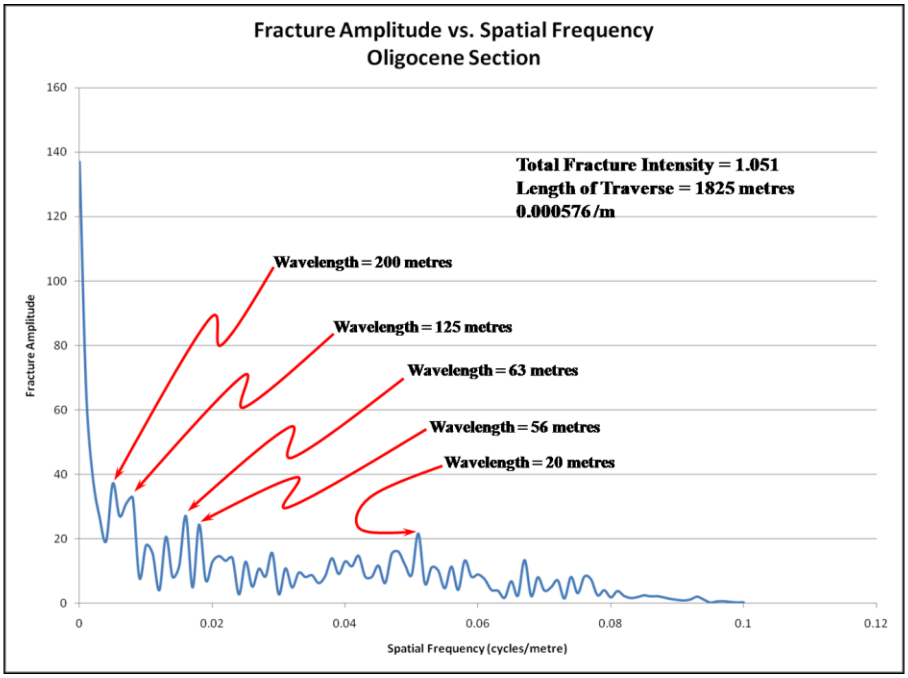

Figure 4: Frequency analysis of the Jeribe Fm. on the backlimb of the Agdagh fold.