AAPG HEDBERG CONFERENCE
"Paleozoic and Triassic Petroleum Systems in North Africa"
February 18-20, 2003, Algiers, Algeria

Natural Fracturing of Rocks in the Southwestern Basins of the Algerian Sahara

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The natural fracturing of rocks can play an important role in the improvement of permeability and may contribute to improve productivity in fields where the primary physical characteristics are poor.

In the Algerian sedimentary basins, principally the southwestern basins, determining the fracture networks has always been the concern of geologists and the role of fracturing has been highlighted in several prospects.

In the Ahnet basin, the production of gas seems to be unrelated to lithological variations in the reservoirs. In these large anticline structures, the presence of gas has been proven in the Cambro-Ordovician reservoir, but only a few production wells have been moderately successful.

This inconsistency is particularly due to the spatial distribution of fractures throughout the reservoir.

In order to investigate different hypotheses, we used several approaches to solve the problems highlighted by the interpreter: essentially understanding the deformation process, prediction of fractured zones and building a discrete model of the fracture network.

This approach combines several methods, including sand box modelling, numerical modelling, and statistical rules, for extrapolating observations from seismic and well data (fractal behaviour of fault families).

Stratigraphic setting

During the Palaeozoic, from the Cambrian to the Namurian, the sedimentation was mainly silicoclastic, related to various depositional environments including continental, marine, glacial and coastal deposits. These deposits lie upon the Infra-Tassillian unconformity.

The source rocks in the basin are essentially the basal Silurian and Frasnian/Givetian hot (radioactive) shales. Some secondary source-rock potential may occur in the median part of the Silurian and Cambro-Ordovician sections. The main reservoir rocks consist of the Cambro-Ordovician sandstone, which present poor quality matrix petrophysical characteristics. These properties are, however, improved by natural fracturing.

Data base

The first step of this work consisted of a data analysis relative to the fractures parameters in order to suggest fracturing models. These data are mainly from outcrops, wells, and 2D seismic.

Structural evolution

This basin is an entity of the Saharan platform.

The present structural style in the Ahnet basin has resulted from its location, on the former Pan-African (750-550 My) orogenic craton and from the principal tectonic phases the basin has undergone.

The structural evolution of the basin began at the end of the upper Devonian followed by a strong subsidence, but the main structures have been formed subsequent to the major orogeny Hercynian phase.

Methodology

This approach combines several methods, including (a) sand-box modelling, and (b) numerical modelling. Statistical rules, often can be related with fractal behaviour of fault families, in order to extrapolate observations from seismic and from well imaging (FMS) logs.

The simulated deformation is not unique because of the variability of parameters.

(A) Sand-box modelling

Sand-box modelling is a supplementary tool used with the aim of understanding the deformation of the earth's crust. The experimental technique is based on a rheological model of lithosphere with brittle (sands) and ductile (silicone) behaviour.

The shear bands have an internal **dilatancy** and propagate as fractures which can be observed using the scanner

(B) Numerical modelling

For a better understanding of the evolution and of the spatial distribution of fractures affecting the structure, a finite elements study was conducted. The numeric model was built from a current geologic cross section based on the surface geology, the seismic sections and the well data.

Numeric analyses were made including linear elastic behaviour and non-linear behaviour of sedimentary rocks. The effect of a listric fault which is genetically related to the formation of the structures, on the spatial and temporal distribution of the fracturing rocks was studied.

Geometrical modelling

Two types of geometrical modelling had been studied:

- The probabilistic modelling of the faults (fractal analysis), the philosophy being to investigate an apparent fractal object at increasingly fine detail. The probabilistic modelling takes into account all the parameters of the faults in the seismic scale as well as the fractal dimension to generate faults which are not solved by the seismic (small scale).
- The analysis of the curvature of reservoir horizons is used to localise zones with strong curvature and to determine the orientations of the associated fractures

Furthermore, we have the possibility of estimating the occurrence probability of opening fractures according to their angle with the maximum horizontal stress.

Results

This determinist approach is based on hypotheses built from the geologic data by taking into account the notions of constraint, deformation, and the rheology. This approach is not restricted to a statistical description of the geometry of fractures observed from wells and outcrops. This allowed better constraint to the extrapolation of specific data of fractures obtained in wells to the whole reservoir.

Outcrops and well results

Outcrop observations provided some parameters relative to the attributes of the fractures in the Ahnet basin.

The technique of the well-imaging provided the characteristics of fractures including identifying open fractures in specific directions.

The individual distinction of every fracture plan allowed to classify fractures in three directional families and to consider that the density of fracturing is similar for every family of fractures. Three fractures families also observed in the outcrops are analysed and their parameters are considered for the calculation of the real spacing between fractures and for the 3D representation of the fracture network.

Sand box modelling results

The sand box modelling experiments help with several hypotheses concerning the process of deformation and the initiation of the major faults in the structures of the central Ahnet. The major hypothesis tested in all the experiments is the reactivation of pre-existing discontinuities (faults) in the basement.

Results of the various experiments show that it is possible to understand the formation process of the structures provided that appropriate models were adopted.

Numerical results

The numeric tool results of mechanical modelling used in this study answer several questions relative to the formation of large anticlines and suggest a possible origin of the variation in the distribution of the naturally fractured rocks. The last part of this work is dedicated to the probabilistic modelling of the sub seismic faults and fractures related to the curvature of folds. The various tests of geometrical modelling allowed us to choose the most realistic network of sub seismic faults and to distinguish the zones where the spatial distribution of this type of faults is the more dense.

Geometric modelling results

These results show localised zones with strong curvature and help determine the orientation of the associated fractures. Estimating the location of zones where fractures might be reopened by the stress field is also possible.

The calculation of the spacing between fractures also helps modify models for the fracture network and determine the direction of the gas flow around the wells. This simulation showed the importance of fractures NW-SE and diaclases at bearing N100 and their contribution to the gas flow.