Introduction

The present paper summarizes the results of the projects in central-south Algeria in the areas of Tinrhert Nord (transition between Ilizzi and Berkine Basins) and M’Sari Akabli (western margin of the Ahnet Basin), targeted at proving the deliverability of already discovered and proven resources, and explore for new reservoir levels and other prospects. For this purpose, a fully integrated multidisciplinary workflow has been applied using up to date technologies which will be illustrated with examples (cf. Nelson, 1987; van Dijk, 1998; Felici et al., 2016).

Extensive analyses of vintage 2d and 3d seismic data and previously drilled wells has been performed over the last 4 years. New 2d seismic data were acquired and vintage 3d seismic data have been reprocessed in various phases. Two wells have already been successfully drilled in the Tinrhert Block, and fracking and testing is ongoing. In total, seven wells are foreseen to be drilled in the two blocks.

Figure 1 (left) Location map of the studied areas in Algeria. Blocks indicated in yellow are the existing licenses, extracted from the IHS World database.

Figure 2 (right) Reservoir layers for the Cambro-Ordovician as established in the Tinrhert Nord Block.

Methodology and Workflow

The seismic interpretation and mapping went through all the classical phases of well log analyses and correlation, seismic to well tie, time mapping of key horizons, 3d fault mapping, 3d velocity modeling and 3d structural mapping in the depth domain. This resulted in a calculation of resources in terms of volumetrics and deliverability, and an extensive mapping of prospectivity for different reservoirs with connected risking and ranking.

Various 3d seismic attribute analyses was applied to enhance the visibility of seismic and subseismic fault and fracture zones. Variance/coherency extraction plus ant tracking (with application of specific shadow zones) was applied to a processed 3d seismic volume. Subsequently the combined attribute was extracted along the grid representing the top of the Ordovician sandstones, the main tight reservoir in the area. A special data driven technique (FD5D; cf. van Dijk, 1998) was applied to these observations in order to generate three-dimensional Discrete Fault and Fracture Networks (DFFN) on a subseismic scale. These models permit to evaluate the connectivity and heterogeneity of major Highly Persistent Fractures (HPF), and Damage Zones or Fracture Corridors, that can be components of flow in the reservoir and contributing to compartmentalization or connectivity on reservoir block / drainage volume scale.

Where the geological structures are outcropping, using them as analogue, an extensive exercise was performed on High Resolution satellite imaginary, especially acquired and elaborated for and by DO, in order to understand the evolution of the geological structures; Structural style, such as the shape of the anticlines, nature of the faults and orientation in space of the anticlines can be reconstructed. On the trace of the seismic line the surface geology is calibrated directly with the seismic image. A complete integration between GIS and seismic interpretation environment was obtained so that the seismic mapping could be calibrated with all the structures visible in outcrop and the interpretation performed in this way integrates the results of the two methods.
Studies of vintage and newly acquired cores focused on conventional description of sedimentological environment, and the description and characterization of fractures and small faults. Analyses of these data have been integrated with the multiscale approach.

**Figure 3** Result of attribute analyses on the top of the Ordovician reservoir in the M’Sari Akabli Block.

The Hoggar Massif along the southern margin of the Ilizzi Basin serves as an analogue for the Paleozoic of the Tinrhert Block (Eschard et al., 2005). An extensive analysis was performed on remote sensing images of the area to obtain information on the fracture and fault network properties. Thousands of fractures have been identified and interpreted over a large area and over a large-scale range. With special

**Figure 4** Examples of the results of remote sensing analyses in the Hoggar area, as an analogue for the tight reservoirs in the Tinrhert Nord Block.
newly designed techniques the fractures have been analyzed focusing on orientation and size distributions. The result of this new approach indicates that a clear distinction can be made between the mathematical properties embedded in the fracture/joint population and those that characterize the fault population. Specific differences exist between the mathematical properties defining size distribution variation in the different scaling domains. Regarding the orientation distribution it can clearly be seen that fault distributions are partially related to reactivated and linked joints whereas some parts of the joint population is pervasive but not represented as faults. This shows that care should be taken when integrating the various segments of the size distribution in the generation of predictive models on a well scale.

The results of vintage image logs and newly acquired image logs, and the interpretation of borehole break out, induced and natural fractures, fault zones and sedimentary facies, have been integrated; This shows that the orientation of the present day stress field is consistent throughout the area with a projected maximum compressional stress axis oriented NNW-SSE. This is also consistent with other information available for the area (World Stress Map compilations and other O&G data). This feature can be used in future well planning (especially future horizontal drains) applying the principle that any fracture set with a favorable orientation with respect to this present day stress field can be considered as potentially contributing to flow of hydrocarbons along the fracture network, being critically stressed and potentially open.

Conclusions

The multidisciplinary and multi-scale approach, using and evaluating numerous crucial parameters from different sources, provides a sound basis for the future planning of exploration, appraisal and development wells in this challenging subsurface environment which shows multiple stacked reservoirs characterized by dual porosity and dual permeability with highly complex three dimensional connectivity and heterogeneous drainage volumes.

Figure 5 Structural model for the evolution of faults and fractures for the Tinrhert Nord area.
References


Figure 6 Three dimensional data-driven Discrete Fault and Fracture Model (DFFN) of a part of the Tinrhert Block. The model was generated using special designed software modules (FD5D; cf. van Dijk, 1998) that connect observations on seismic attributes such as coherency/continuity and ant-tracking, by best-fit solutions in 3d space. Size of the model: 3750 m. Two versions show different shading options (grey scale, below; each feature colored differently, above). The 3d TIN grids represent features (subseismic fault zones, damage zones, and fracture corridors) ranging tens-hundreds of m’s up to km’s. See text for further explanation.

Figure 7 Left: Multiscale Power Law plot of size distributions which integrates the outcropping, remote sense information with subsurface fault and fracture analyses on seismic attributes. The model comprises ca. 2100 fractures on outcrops and ca. 9000 subseismic features. Right: Analyses of the Power Law function parameters versus size distribution. This completely new approach clearly illustrates how fault and joints show different mathematical relationships over scale.