We C2 01

Tracking Fracture Corridors in Tight Gas Reservoirs: An Algerian Case Study

N. Nosjean* (ENGIE), Y. Khamitov (ENGIE), R. Yahia-Cherif (Sonatrach AST)

Summary

The interpretation of faulted systems is an essential step in E&P business, from a proper understanding of prospects to optimal development well placements. The identification of fractured zones within a reservoir, usually characterised by sub-seismic faults, is often neglected, while it can add significant value to the development of a project. The present case study is focused on the very prolific Algerian Ordovician tight reservoir target. It highlights a structure at the end of an appraisal well campaign, where an integrated fracture reservoir study had been performed in order to track efficiently subtle fault corridors.

The utilization of advanced seismic attributes using the Multifocusing technique has proven valuable when determining the detection and extension of fracture corridors within the reservoir. At the well locations, results matched reasonably well with the fracture orientation and density interpreted from cores, borehole images and DST interpretations. This approach has a great value when planning well trajectories, for production predictions, and eventually for locating any future development wells in the area.

Introduction

Building a sound conceptual framework of faulted and fractured systems based on interpretation and complete integration of available subsurface datasets is an imperative step to understand the full prospectivity of fractured reservoir and to narrow down the uncertainties for optimal placement of development wells. Often neglected in the industry, as usually characterised by sub-seismic faults, the accurate identification of fractured zones within the reservoir is an absolute must for proper reservoir assessment.

This case study, located in the Illizi basin (Figure 1), delivers an in-depth scrutiny of the prolific Ordovician reservoir target. It broadly highlights a structure at the end of an active appraisal campaign crowned by an integrated fractured reservoir study to track efficiently subtle fault corridors.

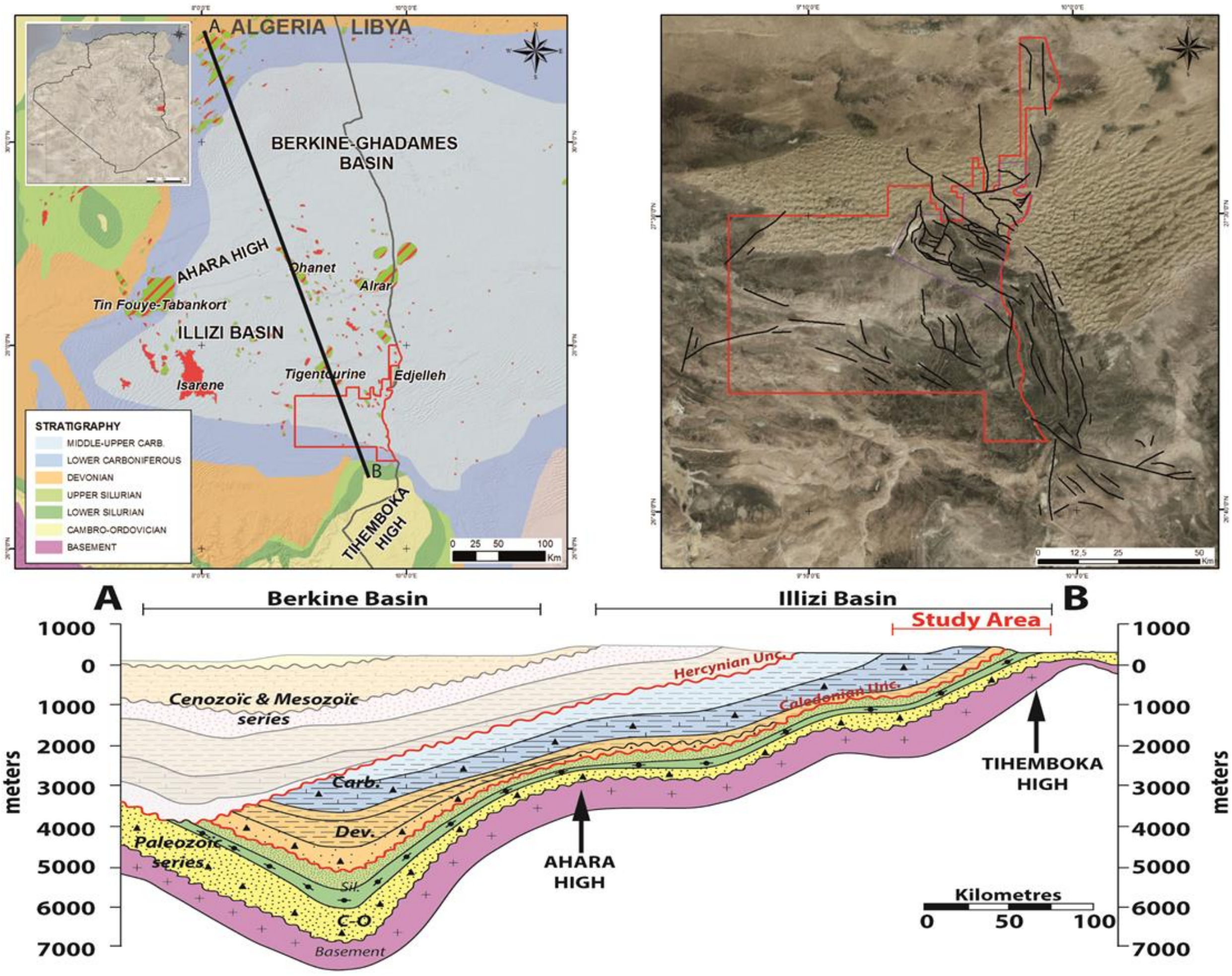

Figure 1: Case study area - Geological & structural maps and cross-section.

General structural setting

The Illizi basin is an intracratonic depocenter bounded to the North by the Ahara High and to the South by the Tihemboka High (Figure 1). This basin has been subject to many compression-extension cycles throughout its history (Klett, 2000). The structural frame and geometry of its sedimentary deposits are largely controlled by Basement faults (Gaelazzi et al., 2009).

In the study area, the observed structures are characterized by high angle north dipping sub-vertical faults, which have created folds with a short and steep frontal limb and a long and gently dipping back limb with a large uplifted area.

Ordovician reservoir highlight

The Ordovician rocks represent one of the three proven petroleum systems in the region, together with the Devonian and Carboniferous series. From a sedimentological point of view, it is a fairly complex system, characterized by a very high lateral variability of facies, linked to a series of complex geometries of glacial erosion surfaces (Nosjean et al, 2016). Reservoirs can represent very thick sand-prone units, even if their petrophysical properties are generally low grade, with effective porosity generally limited to 10%, and permeability varying from 0.05 to 5 mD. These reservoirs are naturally fractured, but those fractures vary spatially in orientation, aperture and density.
The strong positive impact of fractures on permeability and productivity of these tight Ordovician reservoirs has been demonstrated in the area (Le Maux et al., 2006). Understanding the reservoir heterogeneity through faults and fracture corridors tracking, their geometry and relation to hydrocarbon production, is key for maximizing the value of any project in the area.

Integrated Reservoir Engineering & Geological studies

The structure which was selected for this close-up case study is characterized by comprehensive data acquired in three appraisal wells (named A, B and C, located on Figure 3), which include FMI, cores and openhole DST. In most wells, the cores showed limited evidence of natural fractures and some presence of stylolites. The overall good quality FMI allowed the recognition of several features, which were closely analyzed and cross-checked with cores and DST results, then later compared with advanced seismic attributes.

Figure 2 shows an example of the integrated fracture reservoir study performed on well C. At this location are observed East-dipping open fractures, with a N-S maximum horizontal stress direction (open fracture strike). They are in line with the direction of drilling induced fractures.
Well C was hydraulically fractured and the DST operations were subsequently performed, as the modified isochronal test to determine well gas deliverability. Derivative and Horner plot diagnostics confirm the presence of highly permeable matrix (~300md) and tentatively point to a dual porosity reservoir response, in addition to the effect of parallel boundaries in the distant vicinity of the well (300-400m away). These parallel boundaries are too subtle to be seen on conventional seismic, but pronounced enough to alter the pressure transient signal observed in the late time region of the derivative. They very likely represent the effective boundaries of a local fracture corridor.

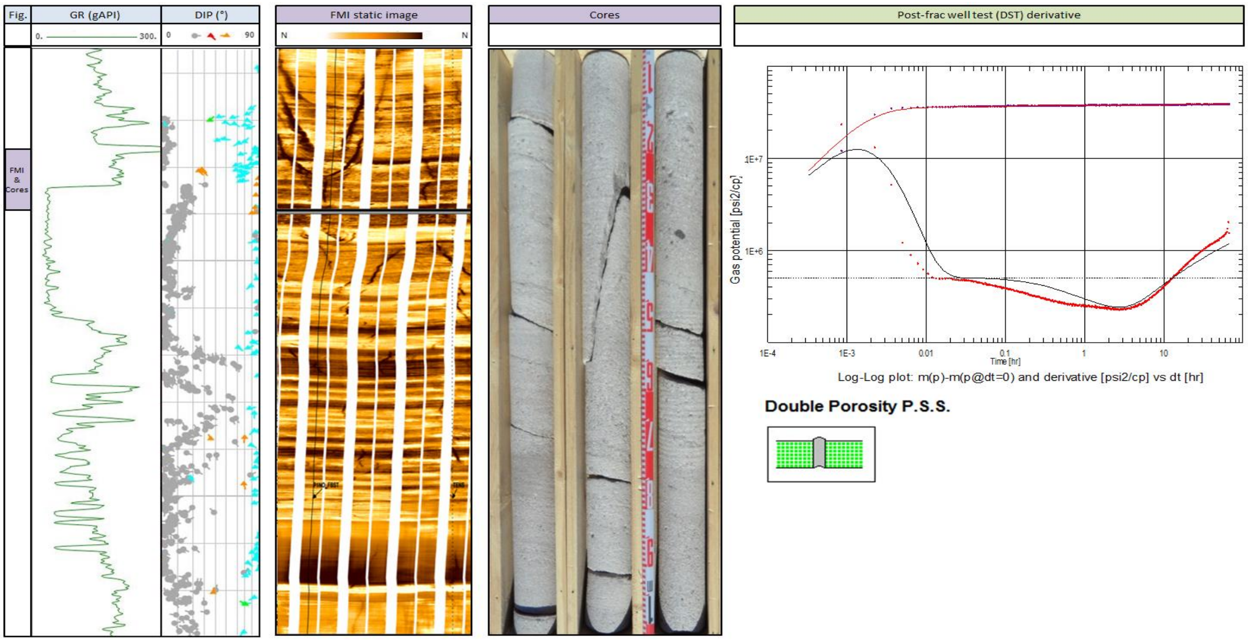

Figure 2 *Well C integrated fractured reservoir study example.*
(FMI and core location highlighted in the first left column).

The integrated interpretation approach of the available well database demonstrates that reservoir around well C is mainly constituted of a highly permeable clean sand reservoir matrix within a natural fracture corridor. This strongly improves the reservoir dynamic performance. On the contrary, well A proves to be located in a less favourable setting.

Integration of Seismic information

Nowadays, there are two main ways to investigate the presence, orientation and density of natural fractures using seismic data. One way is to use the traditional PSTM / PSDM approach, which aims at imaging reflectors. Thanks to diverse attributes, such as coherency and dips, we can track for any reflectors interruptions that arise directly from continuous wave field propagation.
Another approach aims at detecting diffractions along hyperbolas. The multifocusing diffraction method is indeed a well-defined tool to image natural fractures systems (Berkovitch et al, 2009). It enables to generate a new set of attributes which arise directly from the propagation hypothesis of a perturbation.

Key data products, such as energy after reflection attenuation, multifocusing diffraction coherency and RMS velocities, were applied to our case study, through volumes and surfaces attributes extraction. Figure 3 presents a diffraction coherency cross-section going through key wells. We can observe that Well C is located in an area which highlights important discontinuities related to fractures presence, as discussed previously. However, some weak discontinuities are observed on well A location, as also highlighted in the integrated reservoir fracture study.

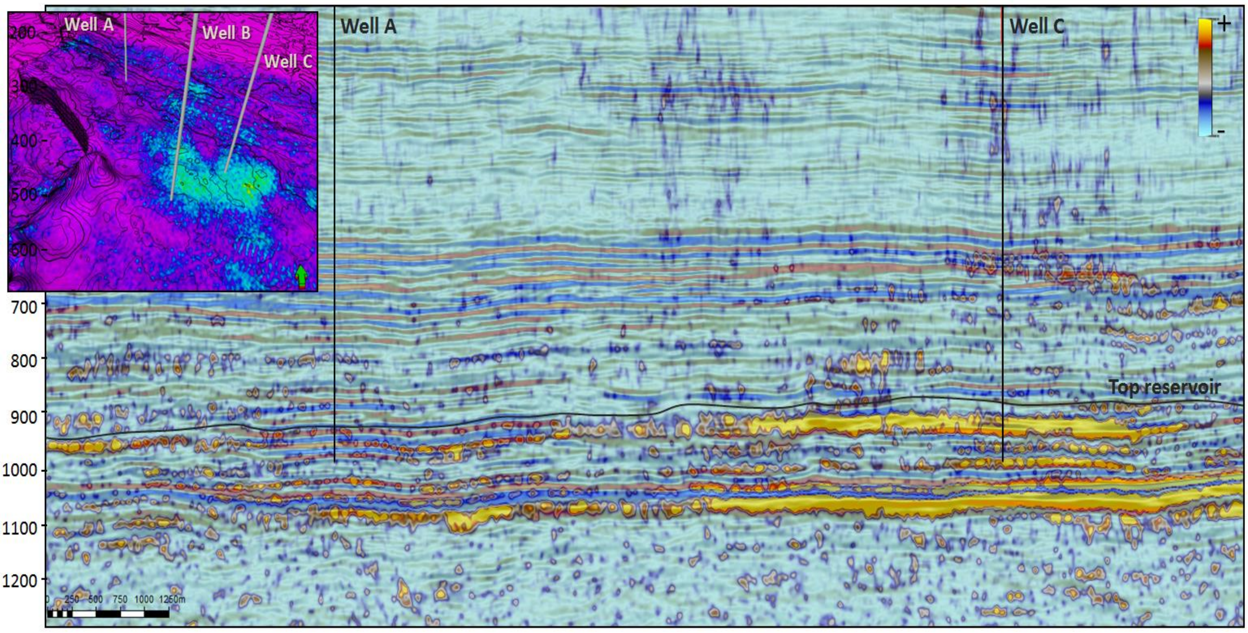

Figure 3: *RMS amplitude map of the diffraction coherency after reflection attenuation and composite section of the PreSTM seismic with diffractivity data overlaid.*

This fractures analysis workflow has also been fine-tuned and compared with traditional attributes related to faulting mechanisms, such as dip-steered seismic coherency, fault detection, seismic curvature and thinning attributes, as well as with isopachs maps to validate faults and fracture identification and stress direction in compliance with well data.

Conclusions

The incorporation of cores, borehole images, well tests and advanced seismic attributes alike showcase the added value to integrated subsurface workflow when detecting fracture corridors and their extension within the Ordovician reservoir.

The coherent match in the azimuth range of faults and fractures between the ones detected from multifocusing attributes calculations and the well data validated the resilience of undertaken approach. This study ascertains the fault location and fracture corridors extension away from the wells, assesses their potential knock-on effects on reservoir deliverability and simultaneously suggests promising location for upcoming development wells. This information will be further used to construct comprehensive Discrete Fracture Network reservoir models with a higher degree of certainty.

Acknowledgements

The authors would like to thank Sonatrach AST for having granted the permission to show this dataset, and Engie for allowing the publication of this abstract.

References

Galeazzi, S. Point, O. Haddadi, N. Mather, J. and Druesne, D., 2009, Regional geology and petroleum systems of the Illizi–Berkine area of the Algerian Saharan Platform: An overview. Marine and Petroleum Geology, pp.1-36

Klett, T.R., 2000. Total Petroleum Systems of the Illizi Province, Algeria and Libya - Tanezzuft-Illizi. In: U.S. Geological Survey Bulletin, Vol. 2202-A

Le Maux T., Murat B., Amamra M., Mesdour K., 2006, The Challenges of Building Up a Geological and Reservoir Model of a Late Ordovician Glaciomarine Gas Reservoir Characterised by the Presence of Natural Fractures. SPE-101208-MS Abu Dhabi International Petroleum Exhibition and Conference, 5-8 November, Abu Dhabi, UAE

Nosjean N., Voutay O., Clerc S., Dupouy M., Lloyd A., Zahir S., 2016, Integrated Post-stack Acoustic Seismic Inversion Case Study to Enhance Geological Model Description of Upper Ordovician. 78th EAGE Conference and Exhibition

Schoepp A., Landa E., Labonte S., 2014 Multifocusing 3D diffraction imaging for detection of fractured zones in mudstones reservoirs. GeoConvention Focus, 8p