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APPLYING FRACTALS THEORY TO PROPAGATE AND MODELISE NATURAL FRACTURES IN TIGHT GAS RESERVOIRS

HAMRA QUARTZITES FORMATION/RHOURDE NOUSS FIELD/ALGERIA

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Abstract

The tight gas reservoir in the "Hamra Quartzites" Formation of the Algerian "Rhourde Nouss" Field is known as one the most complicated reservoirs to drill and to develop. Characterized by poor petrophysical parameters, an intense tectonic history and a non-typical diagenesis, only natural fractures can insure entrapment and drainage of a rich gas, the optimization of the production in these kind of tight gas reservoirs comes through a better knowledge of natural fractures and its networks.

The first drilled wells in "Hamra Quartzites" formation located in Rhourde Nouss region didn't give satisfying results; the successful use of hydraulic fracturation in only one well was a driver to search for new techniques to develop tight gas without additional stimulations.

The fractures corridors interpreted by 3D seismic have been propagated according to "the Fractals theory" in order to build and perform a numerical model of natural fractures, this model had to respect the tectonic conceptual model based on "Riedel" methodology. This fractal model has been tested on a slented well, which confirmed the existence of fracture corridors as simulated by fractals and the good results of the well test were enthusiastic to continue the experience because no hydraulic fracturing or acidizing have been used.

The fracture network was modified in the model after the drilling of each well; every 5 wells a "hidden well exercise" had to be performed in order to get the fracture network more accurate.

12 from the 14 wells drilled thanks to this technique have been tested positively and were in conformity with the final fracture model thanks to a "case by case philosophy" and an enormous number of model versions, because every structural bloc has its proper version of propagation.
This complicated and advanced technique was a success to drill and develop tight gas reservoirs in Algeria. First time used successfully in the world.

Geology of the studied area

Rhourde Nouss region is located in the eastern edge of Amguid Spur and was affected by the Austrian tectonic phase or exactly the Cretacious/Post-Cretacious movements.

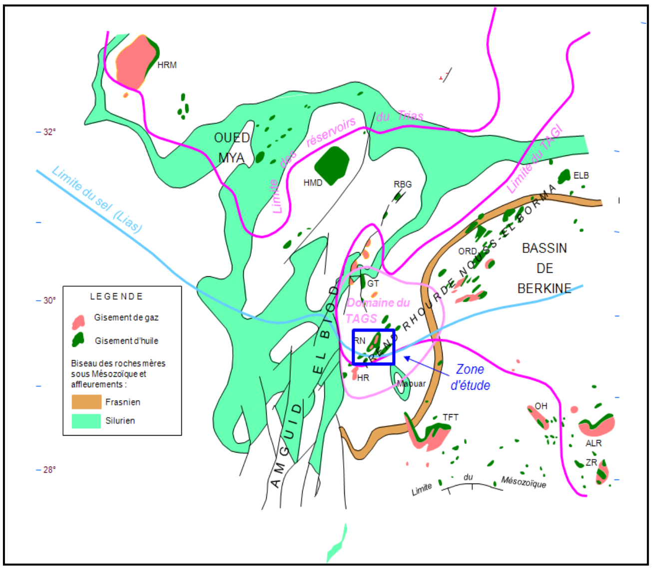

Fig.1. Major geologic elements of the studied area

Characterized by strong structurations, the 14 highs of Rhourde Nouss are dominated by a transpressive tectonic regime (compression a dominant strike-slipping component); it gives the impression that the structures have a rotation axis and not a structural one. This tectonic conjugating compressions and strike slipping was the principal engine of a natural fracturation touching exclusively the tight reservoirs like Grès d'Ouargla and Quartzites of Hamra formations (Lower Ordovician).

The example of Hamra Quartzites formation is particular; The deposits are marine shoreface, low depths, medium to coarse grain size and homogeneous, this reservoir have been transformed through more than 6 diagenetic phases hiding all the sedimentary patterns or visual facieses which caused inhibition of the matrix porosity. The result was a tight reservoir naturally fractured because of multiple post-diagenetic tectonic movements

Until the year 2004, the quantification of natural fractures in core analysis occurred in macro-scale only, when analyzed in microscope and CT scans, multiple micro-fractures have been observed in every thin section and Ct sections analyzed from samples that show macro-fractures.

A first logic relationship has been determined between macro and micro fractures through a conceptual model based on "Riedel" complex movements of 1928, it was not sufficient to explain the complexity of the structural framework.

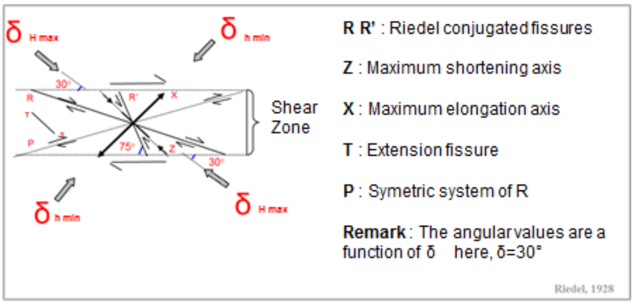

Fig.2.Riedel structural model applied to Rhourde Nouss

The 3D seismic of 2006 helped to extract seismic lineaments (natural fractures) from seismic attributes like coherency cube or low frequencies.

1. PROBLEMATIC

The problem of Hamra Quartzites lies in the fact that its porosity is inhibited by diagenetic multiphase and rarely exceeding 5% and matrix permeability less than 0.1 m incapable of allowing a minimum of gas drainage.

To improve productivity per well we had to find a method of fracture analysis in order to drill wells that naturally produce the expected average flow of 300 000 m3/d of gas with condensate.

2. THE CLASSICAL METHOD

The conventional method for analyzing fractures curvatures extracted from the 3D seismic operations locate lineaments multiple fractures and dispersed without being able to join in a logical and reliable network; curvature shows the result of compression or distension. The limitation is that Rhourde Nouss is affected by the combined movements (transpressions), the strike slipping is the dominant component that never cause curvatures therefore invisible on seismic sections.

Work on time-slice horizontal sections to detect discontinuities lacked precision, so we had to go back to the origin of the major tectonic movements that generated and shaped the structures of Rhourde Nouss region with a new concept.

3. A NEW CONCEPT

The most complicated problems often have the simplest solutions; the application of tectonic model Riedel 1928 structures Rhourde Nouss simplified the problem at the highest point. Indeed, the shape of each structure and its genesis corresponded to the finest detail of the Riedel Model, it became a case study from the year 2006 at the Faculty of hydrocarbons of the University of Boumerdes for every structure shaped by transpressive movements.

The R and R' axes of the Riedel model represented the range of open fractures; $\delta 1$ corresponded to the in-situ stress parallel to the open fractures.

It was necessary to track down the natural fractures that were parallel to $\delta 1$ and modeling single network capable of confirming the tectonic history of the region.

To reconstitute the fracture network, the support of petrographic studies was essential to discover that the sigmoidal shape of micro-fractures observed in thin section is exactly the same sigmoid over 5kms sizes that formed the main structures of Rhourde Nouss ; We proved the fractal correspondence in the axes X & Y.

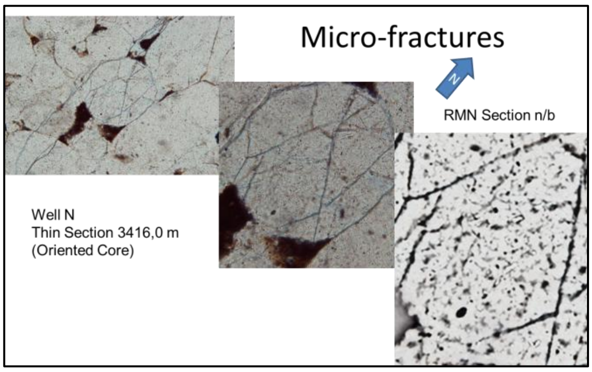

Fig.3 : Fractal events observed from millimetric to microns-scale

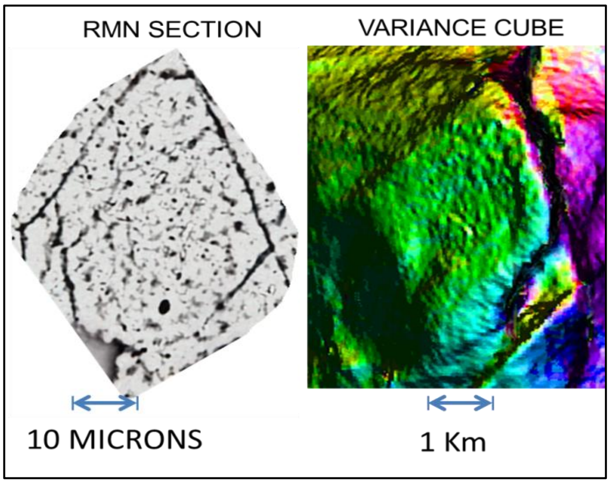

Fig.4. Fractal event from microns to kilometers in XY axes

Analysis of Quartzites cores in several wells showed that the fractal phenomenon also existed in the vertical axis.

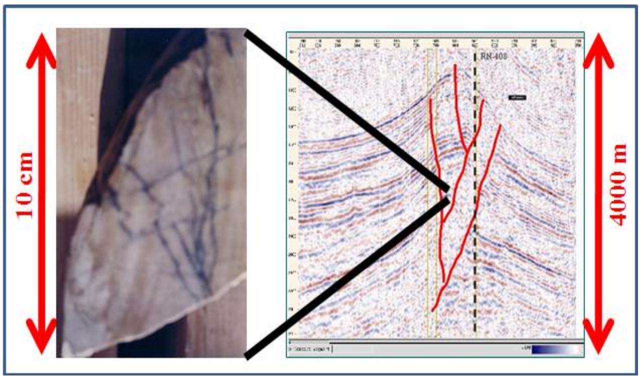

Fig.5. Fractal event shown along the Z axis

The Fractal event being identified, it had to find a way to propagate fractures already detected by seismic lineaments core descriptions and image interpretations in a single network.

4. THEORY OF THE FRACTALS

A fractal is a natural phenomenon or a mathematical set that exhibits a repeating pattern that displays at every scale. If the replication is exactly the same at every scale, it is called self-similar pattern. Fractals can also be nearly the same at different levels.

The term "fractal" is a neologism proposed by Benoît Mandelbrot in 1975 [1] from the Latin root fractus, which means broken, irregular in the "theory of roughness" where fractal refers to objects that have invariant structure under scaling.

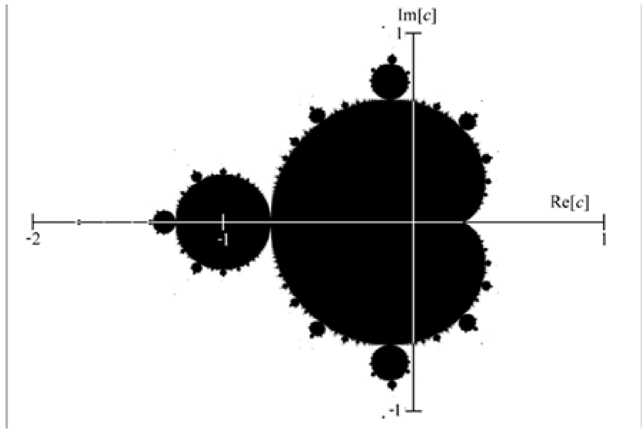

Fig.6.Fractal Geometry of Mandelbrot, 1979

One equation allowed us to unify and propagate detected natural fractures, is the equation of Mandelbrot, father of fractal theory in 1975 which presented an equation emphasizing the self-similarity of some form of the infinitely small to the infinitely large.

When the fractal consists of replicas of itself smaller, its fractal dimension can be calculated as follows:

$$d = \frac{ln(N)}{ln\ (H)} \qquad (1)$$

Where the fractal starting consists of N copies whose size has been reduced by a factor H (for scaling).

5. APPLYING FRACTAL THEORY ON NATURAL FRACTURES MODELLING

For Hamra Quartzite formation in Rhourde Nouss, the auto-similar sigmoidal shapes vary from 20 microns to 5kms; So with finite limits to possible mathematical formulation.

Estimating a geometry for fractal event through natural fractures was necessary to formulate the propagation in the direction of maximum stress δ1, thus the model of Riedel was also spread by fractals and allowed the construction of a conceptual model fractal equated to the phenomena of natural fracturing from transpressive tectonic movements.

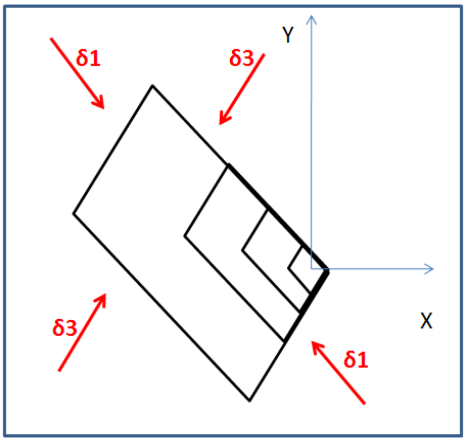

Fig.7.Fractal Geometry of Rhourde Nouss Structure

6. Reference Well

The first simulation by fractal propagation experienced the union of fractures from seismic lineaments and visually analyzed cores.

The following simulation results treated the first interpretation in addition of image log interpretations.

After proving fractality of natural fractures (microfractures, macro-fractures and fracture corridors), we tried propagating a fracture corridor by fractals while eliminating an existing well already drilled, studied and diagnosed (method of the hidden well or "Hidden well analysis"), when we inserted back the real well " reference well " in the propagation of fractures, there was a gap between what is simulated and what is real, but in general the result was convincing to plan a new well based on this study.

The first mission of the new well was to prove the existing of the propagated fracture corridors as simulated by fractals.

Like the reference well, the second well was slented and was oriented to minimum stress in order to catch perpendicularly the natural fractures open by the maximum stress.

This method helped us to have good productive wells of gas with condensate without any use of hydraulic fracturing

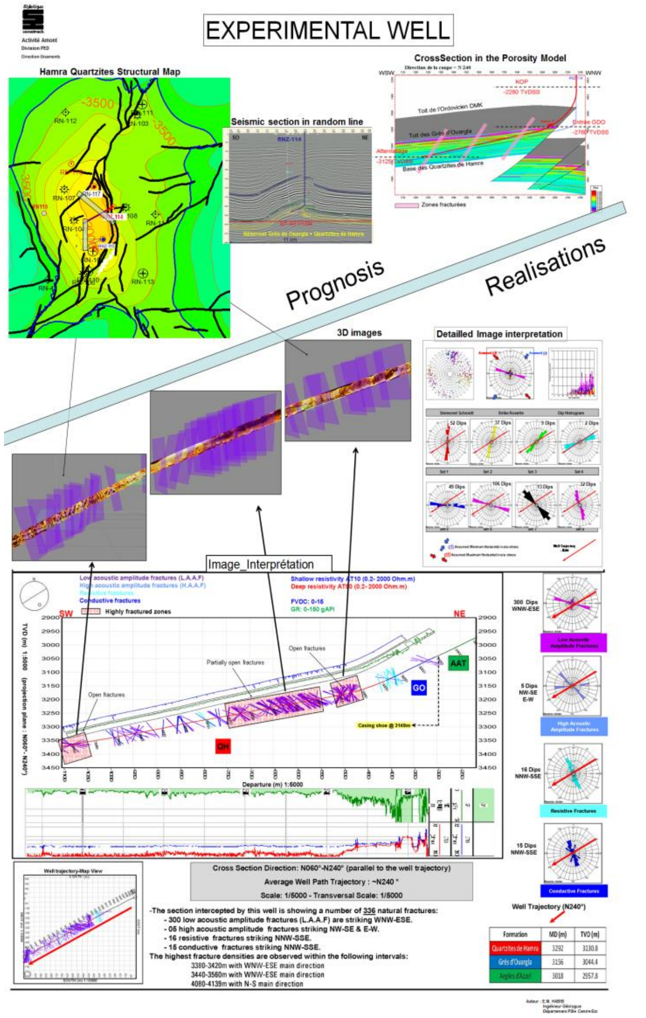

Fig.8. Image Interpretation of the reference well and fracture detection included in the first model

7. FRACTAL PROPAGATION "Tree Fractal Model"

A simple propagation method of the maximum stress directions δ1 was attempted using the propagation of natural fractures corridors through the Direction N300-N330. The algorithm "Tree Factal Model" was performed:

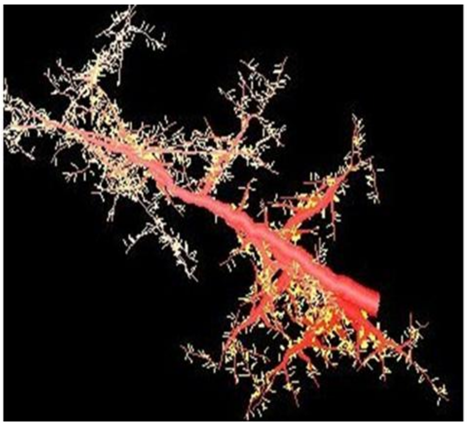

Fig.9. Propagation of Natural fractures by the tree fractal model applied on Rhourde Nouss

8. NATURAL FRACTURES MODELLING

Fractals propagation through δ1 directions allowed us to perfect the model of natural fractures.

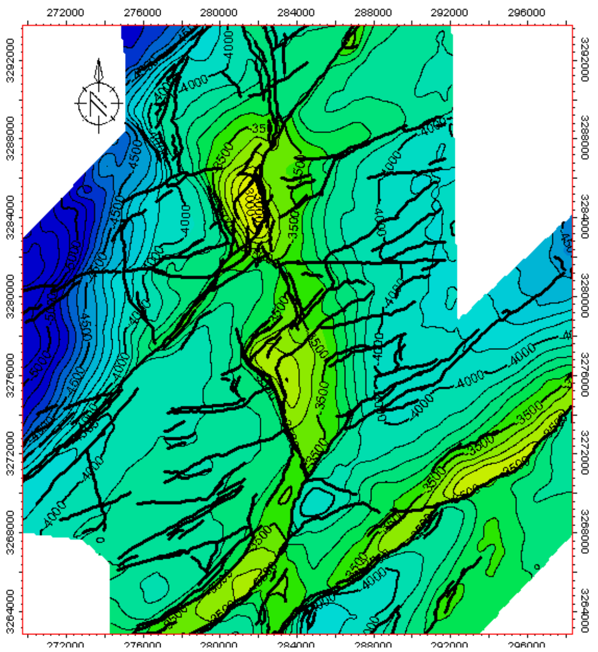

Fig10.Carte Structurale au toit des Quartzites de Hamra de Rhourde Nouss

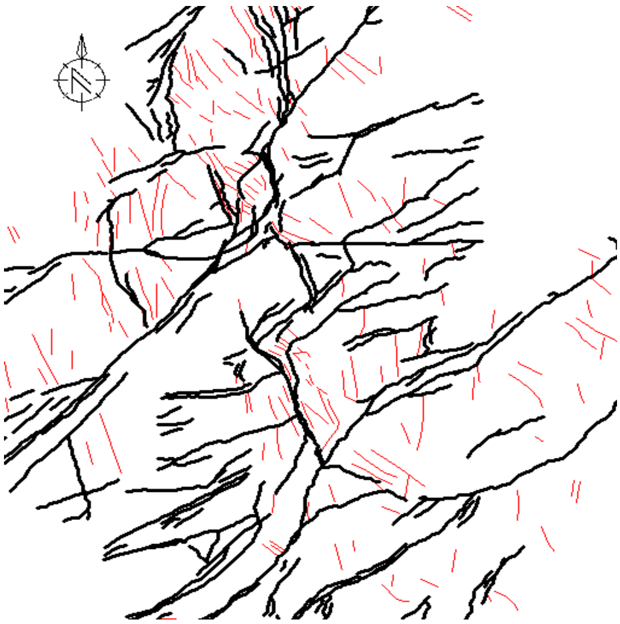

Fig.11.Fractures before fractal propagations

Fig.12.Simulated fractures after fractal propagation

9. Planning new wells

14 wells were drilled in the Hamra quartzites using fractal theory and 12 proved productive, technically successful and confirming the fracture model, where some fracture corridors resulted in areas of mud losses during drilling; areas predicted by the model.

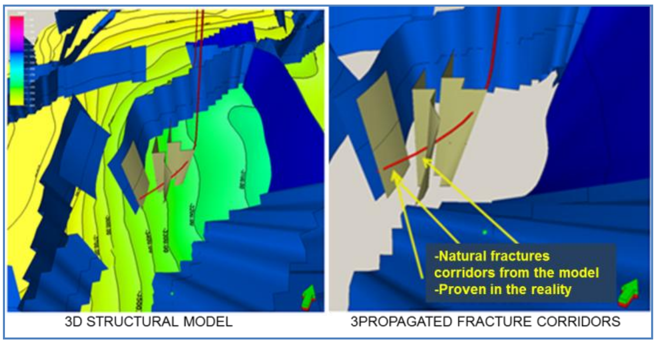

Fig.13. Natural fractures predicted by the model and fracturing encountered by drilling.

With this method, a new design was optimized for well azimuth; parallel to the minimum stress δ3 to drill easily tight formations, perpendicular to the maximum stress δ1 allowing natural fractures to remain open or partially open. The optimization of the inclination (inclined, not horizontal) because of the non typical vertical stress δ2 of Rhourde Nouss region which sometimes has a dip of 20 ° to 30° depending on the structural block studied. The strategy of choosing a well "slented" is no longer to reach a point target but intercept a plane (assimilated to the corridors of fractures) that must cross open fractures in a certain azimuth and a precise inclination.

10. THE EXCEPTION

The 2 wells that did not encounter natural fractures as expected turned out to be wells with a structurally marginal position; it is in fact between two tectonic blocks. An exception that proves the rule, but especially defines its limits.

11. CONCLUSIOINS

The fractal event was indeed proven to natural fractures Hamra Quartzite Rhourde Nouss.

- A fractal geometry of natural fractures was created for the first time in a Tight Gas Reservoir in Algeria.

-A method of fractal propagation for natural fractures was created in PED Division / Sonatrach marking a new aspect of modeling.

-The Only wells that have not had the desired results are the exceptions that proves the rule and define its limits.

-A drilling method has been optimized to produce the Tight Gas reservoirs without using hydraulic fracturing.

REFERENCES

[1] E.M. HABIB: "*Fractured Reservoirs - Hamra Quartzites*", Well Evaluation Conference, Algeria 2007-2008

[2] B. MANDELBROT: "*Les Objets fractals : forme, hasard, et dimension"*, traduction, Flammarion, 1973.

[3] W.RIEDEL, "*Transpression, movements and shapes"* Kansas University translation, Kansas, 1959. "Die konjugierten Schwachstellen von Riedel" 1928