

ANALYSIS OF ROCK MECHANICAL PARAMETERS FROM WELL LOG DATA AND DIPOLE SHEAR SONIC IMAGER. APPLICATION TO ALGERIAN SAHARA "ALGERIA"

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Abstract: The use of ` DSI` (Dipole Shear sonic Imager), in the Tin Fouye Tabankort area in Algeria allowed the exploitation of the rock mechanics properties in the field of drilling having for objective determination of the margin of ability of the well.

The tool ` DSI ` has a considerable advantage by its application which makes it possible to combine the technology of monopole and of dipole and to offer an effective method for the determination of the acoustic dynamic mechanical properties in - situ.

The practical results of this study showed that:

- 1 - The phenomenon of BIOT is less when the medium is impermeable,
- 2- There is a significant effect of the petrophysic properties on the mechanical properties expressed by the effect of the coefficient of BIOT on the variation of the values of the density of mud.

The beach of variation of the stability of the well obtained starting from the tool ` DSI ` lies between the values 1.40 g/cc and 1.80 g/cc. On the other hand the results obtained by the application of Leake-off test and the successive increase in the density of mud vary from 1.50 g/cc with 1.90 g/cc.

With the base of these results, it is necessary to note that the result obtained by tool DSI is almost closer than the practical methods and the percentage of error obtained by the application of this tool is due to the difference between the dynamic and static mechanical properties.

The finality of this study is to determine a field of application of this new technique in the study of the stability of the well during drilling.

Key Words: Rock Mechanical Properties, Dipole Shear Sonic Imager, Tin Fouye Tabankort, Algeria.

I - Introduction

This study aims to determine the rock mechanics properties in-situ by the acoustic method. The exploitation of the rock mechanics properties in the field of drilling aims to determine the margin of the stability of the well.

The rock mechanics tests (uniaxial, biaxial, triaxial and polyaxial) make it possible to determine indeed, at the laboratory the rock mechanics properties. The triaxial compression test consists in causing the rupture of the rock to deduce from it the stress field which represents the test nearest to the conditions of layer.

These properties can be also determined by the acoustic method which consists of the study of the acoustic wave propagation in the porous environment with knowing speeds of the waves of compression and shearing mainly used in this study.

The `DSI tool` has the advantage of recording a certain number of parameters such as speeds of the waves P and S in all the geological formations and this simultaneously. The recording of these parameters enables us to obtain the mechanical characteristics of the formations crossed by a survey.

The essential goal of this study is thus to find a field of application of this new technique in the study of the stability of the wells during drilling.

II – Presentation of the area of study

II.1 - Field of Tin Fouyé Tabankort (Algeria):

The field of Tin Fouyé Tabankort (TFT) is located at approximately 360 km with the SSE of Hassi-Messaoud and 200 km in the North of In-Aménas. L' Ordovician are impregnated of oil on most of the Northern repercussion of the anticlinorium of Tin Fouyé .L' extension of accumulation is delimited in the East and the West by two major accidents, North by the aquifer and the South by a gas-course (Fig.1).

II.2 - Structure:

The layer of Tin Fouyé Tabankort belongs to a complex anticlinorium of regional extension and comprising structures aligned along the major accidents. The tank is recue by various faults of orientation which delimit the compartment of Sub meridian orientation.

The rejections are very variable and can exceed hundred meters along the major accidents. These faults are generally Sub-verticals of the normal type and sometimes opposite. The formations met go from Precambrian to the Cretaceous including the tank Ordovician, the cover of this last is ensured by 2000 m of often argillaceous sedimentary deposits. The geological analysis made it possible to vertically subdivide the communicating reserve in two sets superimposed on knowing:

a whole higher with thicknesses varying from 10 to 20 m and a whole Lower with thicknesses varying from 0 to 60 m.

The distribution of the fluids on the level of Ordovician of the field of TFT is controlled by a hydrodynamic current of acquires.

III - data Acquisition and processing of the `DSI tool`

1 - Presentation of the tool:

The`DSI tool` (Fig.2) represents rising generation of the sonic tools compared to the other sonic tools where the monopoles are limited by the physical properties of the borehole: the latter can thus detect only the signals which have a speed higher than that of the sound in the mud of drilling from where importance of `DSI` to mitigate this disadvantage.

`DSI` combines the technology of the monopoles and the dipoles to offer an effective method for the recording of the waves of compression, shearing and Stoneleigh like their slowness's.

The monopoles or the tools with only one transmitter use a source of pressure which creates on the training level a wave compression it and when this wave enters

the formation creates a thin bubble around the wall of the borehole.

we can record the waves of shearing if the speed of the waves of shearing in the formation is higher at the speed of the waves of compression in mud (Formation lasts).

We cannot record the waves of shearing if the speed of the waves of shearing is lower at the speed of the waves of compression in mud (tender Formation).

The fashions of operations during the recording are varied:

* Dipole mode: for each dipole (upper, lower) there are 8 traces with 512 samples per trace and during 40 ms.

* Mode of Stoneley: 8 traces are the results of the emission of an impulse starting from the monopole with frequencies contents low.

* Mode P and S: even thing that with the mode of Stoneley but with high frequential contents of the impulse

* Mode FMD: "First Motion Detection": in this mode, only the first arrivals are recorded.

2 - Applications of `DSI`:

The essential applications of the tool `DSI` are:

- Analyze of rock mechanics properties,
- Evaluation of the formation,
- Geophysical interpretation.

This application of the mechanical properties concerns:

- **The stability of perforation or analysis of sand:**

The importance of the application of the mechanical properties is the identification of the zones which would produce sand under the production.

- **Determination height of the vertical hydraulic fracturing:**

The most significant factor to determine the vertical height of the hydraulic fracturing is the difference of the constraints in-situ.

- **The stability of the well:**

The stability of the well poses the problem of the determination of the range of

variation of the mud pressure to prevent the hydraulic fracturing and the crumbling during drilling.

- **Evaluation of the formation:**

This application consists of the detection of the fractures and the identification of gas in the formation, by using the relationship between the slowness of shearing and compression. If this report/ratio is lower than 1.8, the zone contains gas (Fig.3).

- **Detection of the fractures:**

A delay is noticed on the two waves P and S and Stoneley as well as an attenuation of the amplitudes with loss of energy.

- **Application in geophysics:**

This application consists in using the data of "DSI" in certain seismic work like the PSV and the AVO.

3 - Analysis of the rock mechanics properties:

Analysis of the data of the tool `DSI` supplemented by the total density can directly evaluate all the rock mechanics parameters to knowing:

Poisson's Coefficient, for the lateral and longitudinal distortion:

G: Modulus of rigidity, for Pressure applied and the shearing strain:

E: Young modulus, for the uniaxial Constraint applied and the normal deformation:

Kb: Modulate incompressibility, for the hydrostatic pressure and the voluminal deformation:

Cb: Modulate compressibility, for the voluminal deformation and the hydrostatic deformation:

$$\text{Coefficient} = 1.34 * 10^{10}$$

The data processing of the `DSI` tool (Fig.4) uses program STCO (Slowness Time Coherence), technique developed by two researchers: Kimball and technical MRZE (1984). This is similar to that used into seismic in the analysis speed: it is a question of finding a speed for each in-depth position, giving better a summation in coherence of the eight recorded traces

and this in a fixed window which moves along the axis of time (fig.5).

The readings of well log data: "DSI" made it possible to highlight the following data:

- The time of course of shearing $\Delta T_s = 206.25 \mu s/ft$
- The time of course of the wave of compression $\Delta T_c = 102.5 \mu s/ft$
- Measured bulk density $\rho_B = 2.0 \text{ g/cc}$
- The depth $H = 6719.08 \text{ feet}$
- The data of laboratory are :
 - Resistance to the tension $T_o = 1400 \text{ psi}$
 - The internal angle of friction $\phi = 24.5 \%$.

1- Calculation of the gradients of pressure of pores and the gradient of the vertical constraint :

$$P_p = \frac{H * d}{10} * 14.22 \text{ psi} = 1.52 \text{ psi}$$

$$\sigma_z = \int \rho * Gdh = 1.04 \text{ psi/ft}$$

The ratio between the horizontal constraints = 1.2 (σ_H)

2- Calculation of coefficient of Poisson

$$v = \left[\frac{1}{2} (\Delta T_s / \Delta T_c) - 1 \right] / \left[(\Delta T_s / \Delta T_c) - 1 \right]$$

$$v = 0.33$$

3- Calculation of the geostatic or vertical constraint

$$\sigma_z = 1.04 \text{ psi/ft} * 6719.08 \text{ ft}$$

4- Calculation of the pressure of pores far the well:

$$P_p = 1.52 * 2048.5 = 3113.73 \text{ psi}$$

5- Calculation of the mud pressure :

$$p_w = \left[\frac{(H * d)}{10} \right] * 14.22 \text{ psi} = 2912.967 \text{ } \rho_m \text{ psi}$$

6 - Determination of the minor horizontal constraint:

$$\sigma_H = \left[\frac{v}{1 - v} * \sigma_z \right] = 3442.855 \text{ psi}$$

7 - Determination of the higher limit of the density of mud : according to the criterion of rupture in tension :

$$\sigma_{90^\circ} + T_o = 0$$

$$\sigma_{90^\circ} = 3\sigma_H - \sigma_H - \alpha P_w - P_w * \alpha_F (P_p - P_w)$$

From where :

$$P_{wmax} = (3\sigma_H - \sigma_H - \sigma_F (P_p + T_o)) / (1 + \alpha + \alpha_F)$$

Determination of the lower limit of the density of mud from the table-1

Where σ_z , σ_H , σ_{90° given by the following formula:

$$P_w = 3\sigma_H - \sigma_H - 1/\tan^2\beta [\sigma_z - \alpha P_p \text{ Co}] + \alpha P_p$$

Case of impermeable medium

It should be announced that the effective tangential constraint decreases with the increase in the mud pressure. The general formula which determine the lower limit of the density of mud in it is as follows:

$$P_{wmin} = [\sigma_z - (3\sigma_H - \sigma_H) \tan^2\beta + \alpha_F (P_p)(1 - \tan^2\beta) - \text{Co}] / (\alpha_F - \alpha - 1) \tan^2\beta + (\alpha - \alpha_F)$$

Case of a permeable medium

The formula: $\text{Co}/T_o = (1 + \sin\phi)/(1 - \sin\phi)$ in the criterion of "Mohr Coulomb".

α	Pw max	Pw min	ρ_m max	ρ_m min	$\Delta\rho_m$
0.7	4486.12	4062.66	1.54	1.39	0.15
0.8	4149.44	3884.82	1.42	1.33	0.09
0.9	3832.56	3709.59	1.32	1.27	0.05
1.0	3533.78	3573.23	1.21	1.21	0.00

Table - 1 : Determination of the margin of the stability of the Well for $H = 0.7$

$$H = 0.7, F = 0.851$$

$$P_{wmax} = \frac{7597.079 - 2643.775\alpha}{1 + 0.40 \alpha}$$

$$P_{wmin} = \frac{13036.428 - 3754.731\alpha}{2.417 + 0.207 \alpha}$$

From the equations (4) and (2) we determine, for various values of α and H, the equations of the following table:

α	Pw max	Pw min	ρ_m max	ρ_m min	$\Delta\rho_m$
0.7	5299.39	4077.0	1.82	1.40	0.42
0.8	4993.12	3897.24	1.71	1.34	0.37
0.9	4692.1	3719.46	1.61	1.28	0.33
1.0	4359.98	3543.62	1.50	1.22	0.28

Table - 2. H = 0.8 we have: F = 0.901 is:

$$P_{wmax} = \frac{7597.079 - 2805.461\alpha}{1+0.099 \alpha}$$

$$P_{wmin} = \frac{13036.428 - 3975.379 \alpha}{2.417+0.140 \alpha}$$

α	Pw max	Pw min	ρ_m max	ρ_m min	$\Delta\rho_m$
0.7	5299.57	4096.66	1.83	1.41	0.42
0.8	5029.47	3915.57	1.73	1.34	0.39
0.9	4722.34	3735.50	1.62	1.28	0.34
1.0	4418.14	3556.45	1.52	1.22	0.3

Table - 3. Determination of the margin of the stability of the Well for H = 0.9:

$$H = 0.9, F = 0.951$$

$$P_{wmax} = \frac{7597.079 - 2958.034 \alpha}{1 + 0.05 \alpha}$$

$$P_{wmin} = \frac{13036.428 - 4191.534 \alpha}{2.417 + 0.07 \alpha}$$

α	Pw max	Pw min	ρ_m max	ρ_m min	$\Delta\rho_m$
0.7	5417.48	4115.82	1.86	1.41	0.45
0.8	5106.1	3933.27	1.76	1.35	0.41
0.9	4793.73	3750.72	1.65	1.29	0.36
1.0	4483.36	3568.18	1.54	1.22	0.32

Table -4: Determination of the margin of the stability of the well for H=1.0; H =1.0 , F= 1.0

$$P_{wmax} = \frac{7597.079 - 2805.461\alpha}{1}$$

$$P_{wmin} = \frac{13036.428 - 3975.379 \alpha}{2.417}$$

CONCLUSIONS

By this application which makes it possible the combination of the technology of monopole and dipole in order to offer an effective method for the determination of the dynamic mechanical properties in situ, "DSI tool " has an advantage considerable's study of the stability of the Well, based on the knowledge of rock properties mechanics makes it possible to estimate the state of the constraints in the vicinity of the Well which determines the beach of the density of mud corresponding to a Well. The practical results of the stability of the Wells obtained by this study show that:

- The phenomenon of Biot is less when the medium is impermeable,
- There is a significant effect of petrophysical properties on the mechanical properties expressed by the effect of Biot coefficient on the variation of the beach of the density of mud.

- The margin of the stability of the Well obtained by the application of tool "DSI" is given by the following result:

From **1.40 g/cc to 1.80 g/cc.**

The results obtained from the application of the "Leak-off" test and the successive increase in the density is:

From **1.50 g/cc to 1.90 g/cc.**

On the basis of these results, it is necessary to note that the result obtained from the «DSI» tool is more realistic than that obtained by the classical method.

The percentage of error obtained by the application of this tool is caused by the difference between the dynamic and static mechanical properties.

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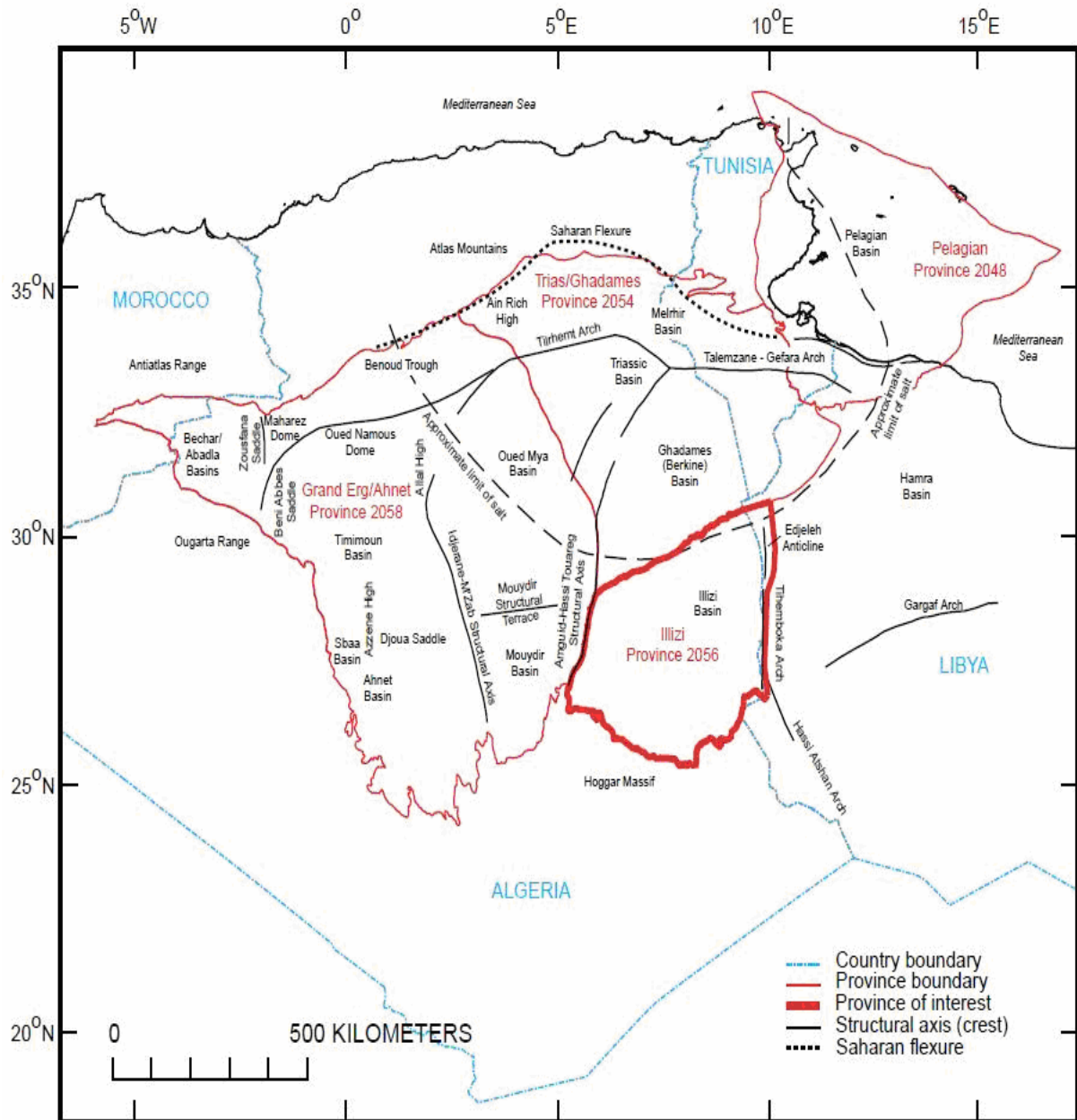


Figure 1. North-central Africa, showing USGS-defined geologic provinces and major structures (modified from Aliev and others, 1971; Burolet and others, 1978; Montgomery, 1994; Petroconsultants, 1996b; Persits and others, 1997).

Fig.1 – Field Location of Tin Fouye Tabankort

DSI Tool

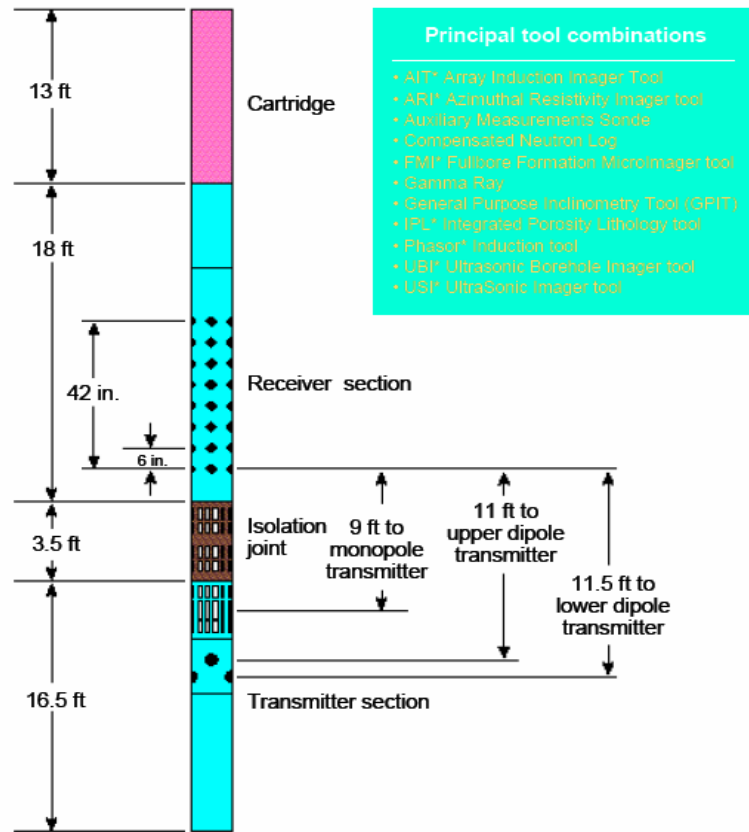


Fig.2 – Dipole Shear Sonic Imager (DSI)

Soft Formation — Monopole

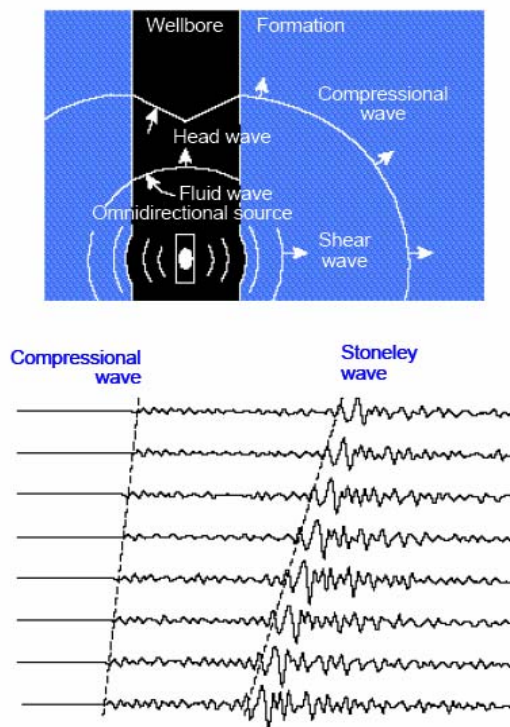


Fig.3 – Soft Formation Monopole (DSI)

STC Computation

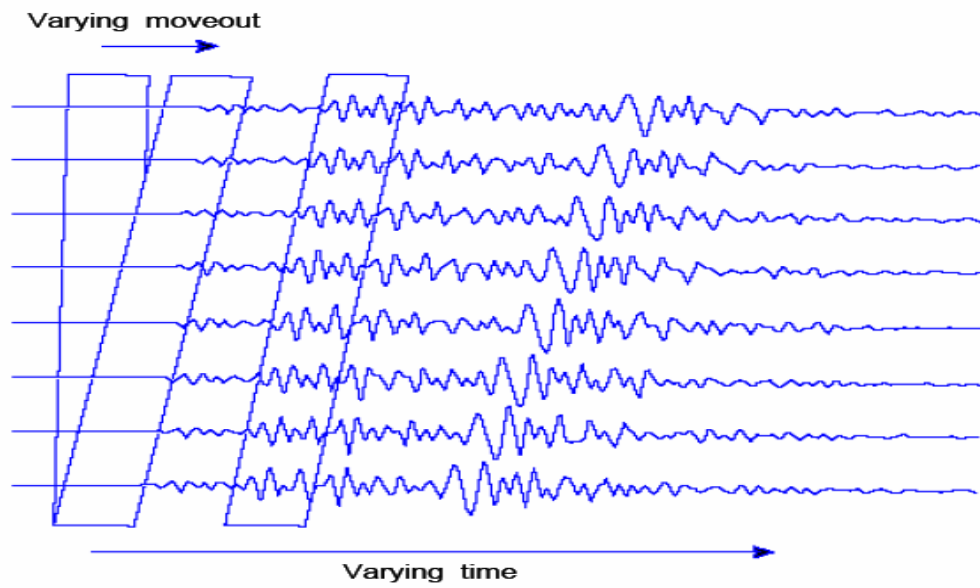


Fig.4 – Slowness Time Coherence (STC)

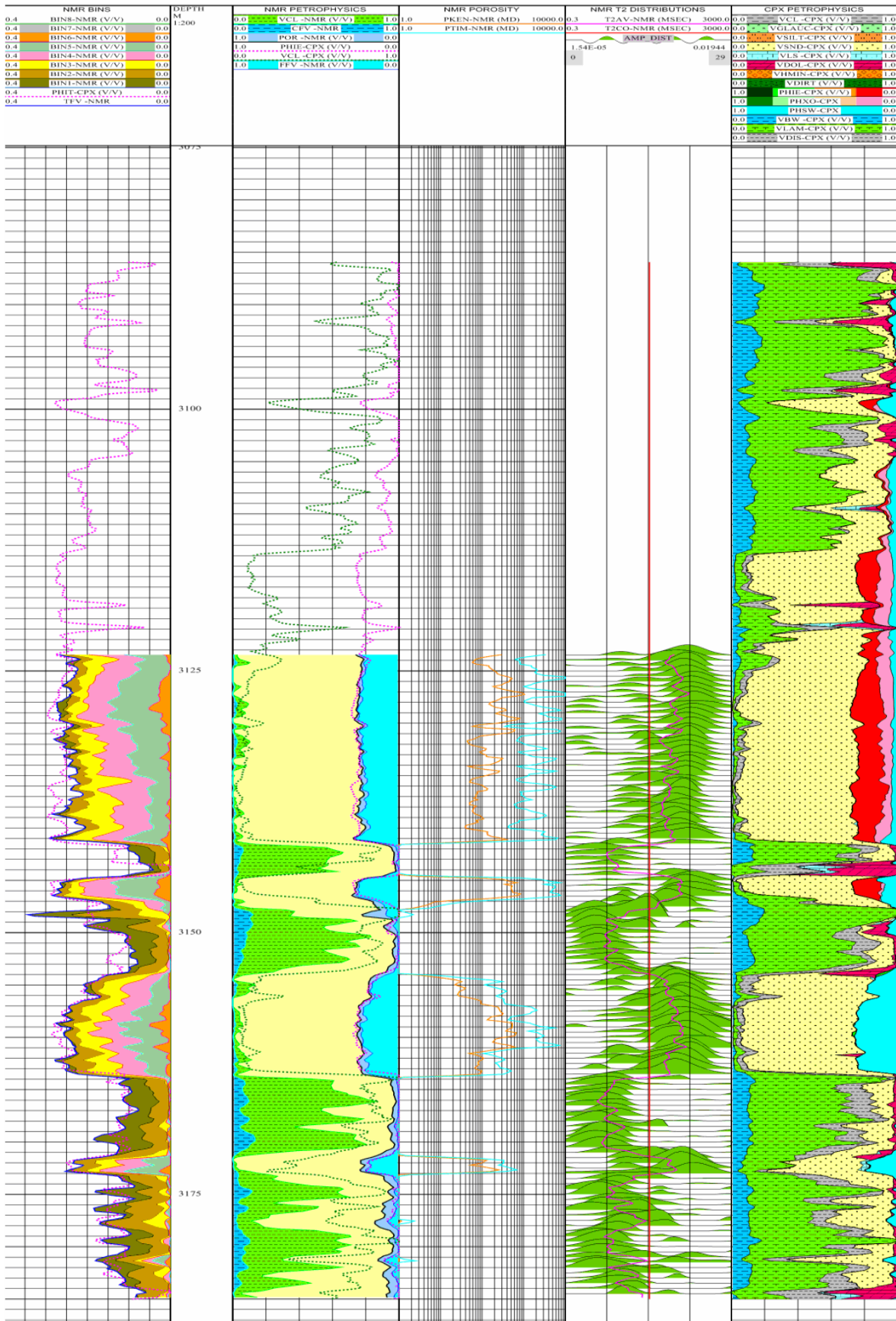


Fig.5 – Volumetric analysis of the formation