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HIGHLIGHTING THE OVERPRESSURED FORMATIONS DURING DRILLING OIL AND GAS WELLS WITH APPLICATION ON TOTEA-VLADIMIR STRUCTURE (GETIC DEPRESSION)

PHD THESIS SUMMARY

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Introduction

The study of abnormal pressurized formations represents an area of interest in drilling oil and gas new wells.

My personal motivation to study this phenomenon started with my job as a petroleum engineer for a service company in oil and gas industry, when I saw different drilling problems caused by kicks while drilling and through this paper I attempt to highlight the estimation of pore pressures that caused by this problems, with application on Totea-Vladimir structure. In this way we can drill future wells on this structure in a safety manner.

Searching for data about Totea-Vladimir structure lead me to limited information and about Getic Depression I saw that many authors have contributed to a better understanding of the geology of this area.

In these conditions using specialty literature and data recorded during drilling the wells on Totea-Vladimir structure, I tried to use different methods for prediction and detection of real time pressure anomaly and in the same time I tried to develop some of them.

Chapter 1. Geology of Getic Depression

1.1. Location

Totea-Vladimir structure is located in villages Hurezani and Licurici (SE of Gorj County), on the road between Craiova and Târgu Jiu at 50 km SE of Târgu Jiu. The name of the structure comes from two villages located in the area, Totea and Vladimir. Geographical this region belongs to central-western part of the Getic Plateau.

1.2. Stratigraphy

After (Mutihac & Mutihac, 2010), the Getic Depression functioned as a sedimentary basin starting from Paleogene and ending in Quaternary with Frățești Formation. Through these deposits, with a thickness of 6000 m (Răbăgia & Mațenco, 1999) there are two discontinuities: one specific to Early Miocene and the other one specific to Early Sarmatian. These discontinuities separated de sedimentary deposits of Getic Depression in three cycles of sedimentation (Mutihac & Ionesi, 1974; Mațenco et al., 1997b; Răbăgia & Mațenco,1999; Mutihac & Mutihac, 2010): Paleogene cycle, Burdigalian-Early Sarmatian cycle and Sarmatian-Pliocen cycle.

1.3. Tectonic evolution

Geographically the Getic Depression (Mutihac & Mutihac, 2010) is the E-W sector between Dâmbovița Valley and Danube Valley, in the nord it's limited by Southern Carpathians and in the south it extends to the alignment Gura – Șuții – Bibești – Drobeta - Turnu Severin which correspond in depth with Pericarpathian Fault.

The Getic Depression represent a sedimentary basin which was interpreted by Săndulescu (1984) as foredeep of the South Carpathians, but recent studies (Mațenco et al., 1997b;

Mațenco & Schmid, 1999; Răbăgia & Mațenco, 1999; Tărăpoancă, 2004; Tărăpoancă et al., 2007) revealed a more complex tectonic evolution. Having in mind these theories, the Getic Depression is a complex basin (Perrodon, 1984), named Getic basin in which evolution we distinguished the following tectonic steps:

1. Paleogene (laramian) – early Miocene: foredeep (post-tectonic cover; Săndulescu, 1984);
2. Early Miocene (early styrian; Burdigalian): transtensional basin – extension/transtension NW-SE to NS (Răbăgia & Mațenco, 1999); syntectonic sedimentation of early Burdigalian deposits;
3. Middle Miocene (late styrian; late Burdigalian-Badenian): thrusting and tectonic inversion – contractions NE-SW (Răbăgia & Mațenco, 1999); syntectonic sedimentation of late Burdigalian and Badenian salt deposits;
4. Late Miocene (moldavian): dextral strike-slip NW-SE and foredeep thrusting over Moesian Platform; syntectonic sedimentation of early Sarmatian followed by Subcarpathian nappe stacking (middle Sarmatian; Săndulescu, 1984; Răbăgia & Mațenco, 1999);
5. Late Sarmatian – Romanian: post-collision stage (post-tectonic cover – Dacic basin; Jipa, 2006).

Chapter 2. Geology of Totea-Vladimir structure

The wells of this study are located în the central-western part of Getic Depression and belong to the structural alignment Vladimir-Totea-Colțești oriented NW-SE and developed in the Burdigalian, Sarmatian and Meotian. Around the depth of 3000 m, these wells intersected burdigalian deposits formed from sandstones in alternation with marls. During the drilling of the wells some kicks occurred in the Burdigalian overpressured area under the Badenian salt deposits.

2.1. Stratigraphy

The deposits drilled by the wells through Totea-Vladimir structure belong to the interval Burdigalian-Sarmatian, which were separated in two main units: Suncarpathian Nappe (Burdigalian-Middle Sarmatian) and Dacian Basin (Middle Sarmatian-Romanian).

2.2. Tectonic evolution

Tectonic evolution of the structure corresponds to the main events described for the deposits of Getic Depression. It can be observed the presence of two anticlines located in front of the Subcarpathian Nappe (Totea-Vladimir and Colțești). The shape en echelon of these anticlines reveal the compression movements during the basin formation.

The Late Burdigalian deposits are cut and covered by Badenian salt and shale deposits which form the seal of the trap. The faults from Burdigalian level extend to the base of Badenian and restricts the migration of the fluids up from here.

Chapter 3. Real-time estimation and evaluation of pressure anomalies on the Totea-Vladimir structure

3.1. Estimation of pressure anomalies

3.1.1. d_{cs} exponent

While drilling, indirect indicators such as physical properties of the rocks drilled and drill bit's performance can tell us if we are drilling into a transition zone between normal and abnormal pressurized formations. To detect these changes, we have to permanently monitor and record drilling parameters related to these indicators. After that, these parameters are used for estimation of abnormal pressurized areas.

The most used method for estimation of formation pressure during drilling of wells for oil and gas it's the d_{cs} exponent method, given by equation (Jordan & Shirley, 1966 and Rehm & McClendon, 1971 fide Mouchet & Mitchell, 1989):

$$d_{cs} = \frac{1{,}26 - \log \dfrac{V_m \cdot F(H)^k}{n}}{1{,}58 - \log \dfrac{W}{D_s}} \cdot \frac{\gamma_h}{\gamma_{fld}}$$

where: d_{cs} – corrected d exponent (of compaction) which takes in account bit wear (dimensionless);

V_m – mechanical speed of penetration (m/h);

n – rotations (rpm);

W – weight on the bit (t);

γ_h – hydrostatic gradient (g/cm^3);

γ_{fld} – equivalent circulating density (g/cm^3);

D_s – bit diameter (in).

3.1.2. Sigmalog ($\sqrt{\sigma_0}$)

The result work of Bellotti & Giacca (1978) for highlighting overpressured formation led them to an empirical relationship given by:

$$V_m = \frac{1}{\sigma^2} \cdot n \cdot \left(\frac{W}{D_s^2} \right)^2$$

The sigmalog parameter (σ) has the following equation (Bellotti & Giacca, 1978):

$$\sqrt{\sigma_t} = \frac{W^{0,5} \cdot n^{0,25}}{D_s \cdot V_m^{0,25}} + 0,28 \cdot (7 - 0,001 \cdot z)$$

Later the authors applied a correction for differential pressure:

$$\sqrt{\sigma_0} = F \cdot \sqrt{\sigma_t}$$

where: $\sqrt{\sigma_0}$ – the rock strength parameter (dimensionless);
F – correction factor for differential pressure.

3.1.3. Sigmalog calculated by d_{cs} exponent

Because Bellotti & Giacca developed sigmalog parameter for Po Valley (Italy) and some parameters were established for the lithology of that area, the successful implementation on Totea-Vladimir structure bear some doubt.

In this context we propose a new parameter for estimating overpressurized areas, $\sqrt{\sigma_{dc}}$ and the final equation takes the form:

$$\sigma_{dc} = \left(\frac{W}{D_s^2}\right) \cdot \sqrt{\left(\frac{W}{D_s}\right)^{-\frac{\gamma_{fld}}{\gamma_h} \cdot d_c}}$$

Conclusions

The successful application of this new parameter $\sqrt{\sigma_{dc}}$ on Totea-Vladimir structure involved the following:

- we calculated d_{cs} exponent;
- we calculated σ_{dc} according the above equation;
- we added a correction for depth;
- we established the normal compaction trend for Totea-Vladimir structure;
- the final values were plotted as a function of depth and the results were satisfactory, because the entry into overpressurized zone from Burdigalian deposits belonging to Totea-Vladimir structure, was clearly highlighted.

3.1.4. Bourgoyne and Young method (1974)

In 1974, Bourgoyne & Young (Bourgoyne et al., 1986) proposed a model for calculating mechanical speed of penetration as a function of several variables including pore pressure gradient.

For highlighting overpressurized areas, authors have developed a drillability parameter (K_p), given by:

$$K_p = \log\left[\frac{V_m \cdot e^{a_7 \cdot H}}{\left(\frac{W}{4 \cdot D_s}\right)^{a_5} \cdot \left(\frac{n}{60}\right)^{a_6} \cdot \left(\frac{F_j}{1000}\right)^{a_8}}\right]$$

3.2. Estimating pressure anomaly

Formation pore pressure was estimated with a better accuracy through Bourgoyne & Young’s method and parameter $\sqrt{\sigma_{dc}}$.

Conclusions

After applying various methods for pore pressure estimating on Totea-Vladimir structure, reached the following conclusions:

- Romanian-Dacian interval consists from consolidated deposits with a normal pore pressure gradient between 0,97-1,09 $kg/cm^2 10\ m$;
- Pontian is recognized as a sequence predominantly composed from shales that are still compacting with a pore pressure gradient between 1,05-1,07 $kg/cm^2 10\ m$;
- Meotian is normal pressurized, characterized by increasing water salinity with a pore pressure gradient between 1,07-1,08 $kg/cm^2 10\ m$;
- Sarmatian presents values of rising pore pressure gradient between 1,08-1,54 $kg/cm^2 10\ m$;
- Badenian deposits (excluding salt deposits) shows low thickness with a formation gradient between 1,36-1,47 $kg/cm^2 10\ m$, above salt deposits;
- Burdigalian represents the pressure anomaly with values of pore pressure gradient between 1,60-2,20 $kg/cm^2 10\ m$.

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