Didactic Prediction of Pore Pressure: Case study in the Amazon Basin

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Abstract

Drilling a well requires the knowledge and study of several parameters in order to be more successful in the whole process. The study of geopressions that encompasses all the pressures and tensions existing in the subsurface and those that are imposed on the formation are of paramount importance for economic and undamaged drilling. The Amazon basin, because it is a basin in development and with great oil capacity, generates interest in knowledge and study. In this case this work the didactic estimate of bibliographic data are used to classify the pore pressure zones of the theoretical vertical well.

Introduction

The pore pressure, referred to as forming pressure or static pressure, can be defined as the pressure of the fluid contained in the porous spaces of the rock. In petroleum areas, the fluid contained in the formation may be water, oil or gas. The importance of pore pressure is in establishing the weight of the fluid to be used during drilling, which will be responsible for the pressure inside the well (Rocha & Azevedo, 2009).

The pore pressure is classified into four categories: abnormally low, normal, abnormally high or overpressure and high overpressure. Second Rocha & Azevedo (2009) the pore pressure gradient classification is performed taking into account the pore pressure gradient value and the overload gradient according to table 1. The knowledge of the pressure zone in which an oil well is drilled prevents operational complications known from the oil industry. Estimation of pore pressure is one of the information needed to design a well.

The choice of the Sedimentary Basin of Amazonas aims at the application of the methodology, to the incentive to the training directed to areas in development justified by the lack of technical and operational information within the projects of planning or development of these fields. In the last one, it is observed the work in studies related to geopressions and clay formations. Studies conducted in this basin reveal great potential to find oil fields in areas not yet available in the ANP auctions. These possibilities corroborate the need to carry out a study of pore pressure classification in the Amazon basin.

Abnormally low	Gp < 8,5 lb/gal
Normal	8,5 lb/gal < Gp < 9,0 lb/gal
Overpressure	9,1 lb/gal < Gp < 90 % Gov
High overpressure	Gp > 90 % Gov

Table 1: Classification of Pore Pressure Gradients. Source:Rocha & Azevedo - 2009

Method

In the present work the methodology consists of visualizing the didactic application of a simulation on the classification of the pore pressure value of a fictitious vertical well based on petrophysical modeling information, following the methodology proposed by Rocha & Azevedo (2009) applied to the Amazon Basin through geoscientific information. The data entry is based on the analysis of the physical properties of the Amazon basin, associated to the data of thickness and density obtained in the work of Nazaré (2007), in order to construct a well project, with 3064 meters of depth to be reached the top of the reservoir.

Subsequently, a drilling project is developed encompassing the lithologies to be crossed taking into account its characteristics and application in the upstream sector (Exploration and Field Development).

The theoretical modeling is based on the approximate estimate of the geopressions determining the pore pressure and overload gradients, which are obtained through indirect methods, through analytical models, where the approximate values are obtained, thus obtaining the pore pressure estimation. The development of this is the application of free software like Excell as a tool in the estimation of geopressions.

Second Rocha & Azevedo (2009) The gradients provide quantitative values and must follow a sequence for the calculations. First the overload gradient, followed by the pore pressure gradient and finally the pore pressure rating.

Initially the overload pressure defined as:

$$\sigma_{OV} = 1,422\ (\rho_w D_w + \Sigma\ \rho_{bi}\ \Delta D_i) \quad (1)$$

At where:

σ_{ov} = overload pressure, psi

ρ_w= density of seawater, g / cm^3

Dw= water depth, meters

ρbi = density of each formation layer, g / cm^3

ΔD_i= depth intervals, meters

After calculating the tension, we calculate the overload gradient.

$$G_{OV} = \sigma_{OV} / C^*D \quad (2)$$

At where:

G_{OV}= overload gradient, lb / gal;

σ_{OV}= overload pressure, psi

D= vertical depth, meters

C=. unit conversion constant.

For exploratory wells, seismic data will be used in this work. Starting from the values of densities already found, we calculated in each formation the parameter observed, which in this work is the transit time, through the Bellotti Method.

$$T_{TO} = (\ 0,23 / \rho\ )^{4} * 10^{6} \quad (3)$$

At where:

T_{TO} = observed transit time

ρ= density of lithologies

With the data of the transit time and the depth of the lithologies it was possible to draw a graph and in it the trend curve, thus finding the value of the normal line for the transit time. According to Rocha & Azevedo (2009), the slope of the trend line can be obtained by the following equation:

$$m = (\ \mathrm{Log}\ (TT) - \mathrm{Log}\ (TT_1))\ /\ D - D_1 \quad (4)$$

$$TT_n = TT^*\ (10)^{m\ (D - D1)} \quad (5)$$

Then, calculate the pore pressure gradient by the Eaton Method, with the following formula:

$$G_P = G_{OV} - [\ (G_{OV} - G_N) * (\Delta t_N / \Delta t_0)^E \quad (6)$$

G_P = Pore Pressure gradient, (lb / gal)

G_{OV}= overload gradient, (lb / gal)

G_N = normal pore pressure gradient, (lb / gal)

Δt_N = value of the normal line for transit time

Δt_0= observed transit time

E = exponent of Eaton

With the estimation of the geopressions, the planning of the number of phases was determined based on Thomas (2004). Thus an oil well is drilled in phases, determined by the diameter of the drill or the reamer being used in drilling. The number of these depends on the characteristics of the perforated zones and the final depth of the well, being usually used of three to four phases, and can reach up to eight. The reasons for drilling in phases are associated with pressures and tensions existing in the subsoil and all those that are imposed on the formations.

Results

Among the parameters used to estimate pore pressure, Rocha & Azevedo (2009) report the need for a wide variety of data, such as electrical profiles, seismic velocities and occurrences recorded in drill bulletins.

From the bibliographical survey and the analysis of the main petrophysical characteristics of the Amazon Basin, a theoretical geological prospect of an oil well was constructed, data of entrance, where the data collection necessary to calculate the geopressions, are expressed in the table 2, 3 and 4.

Formation	Lithology	Thickness (m)	Depth (m)
Solimões	Sandstone	290	290
Andirá	Siltite	725	1015
Soleira	Diabase	264	1279
Nova Olinda	Anhidrite	120	1399
Soleira	Diabase	107	1506
Itaituba	Calcareous	420	1926
Soleira	Diabase	78	2004
Monte Alegre	Sandstone	140	2144
Faro	Sandstone	500	2644
Oriximiná	Siltite	420	3064

Table 2: Input data

Formation	Speed P (m/s)	Speed S (m/s)
Solimões	2000	1000
Andirá	2800	1617
Soleira	5000	2887
Nova Olinda	6010	3370
Soleira	5500	3175
Itaituba	5800	3349
Soleira	6200	3580
Monte Alegre	4500	2598
Faro	4500	2598
Oriximiná	4200	2425

Table 3: Speed input data

Formation	Density (g/cm3)	Observer Transit Time (TTo) (µs/ft)
Solimões	2,2	119,4594802
Andirá	2,67	55,06381515
Soleira	2,56	50
Nova Olinda	2,96	51
Soleira	2,56	52
Itaituba	2,71	51,8840872
Soleira	2,75	48,9306031
Monte Alegre	2,64	57,60970304
Faro	2,64	57,60970304
Oriximiná	2,8	45,52806773

Table 4: Density input data and Observer Transit Time

Considering the thickness and depth of the basin formations, the sequential calculations described in the methodology are performed, obtaining the values of the overload gradient.

Considering the results of the Overload Gradient, Gov, we were able to measure the values of the pore pressure gradient, Gp, as shown in Table 6.

Depth (m)	**Overload Gradient (lb/gal)**
290	18,35915493
1015	21,16071429
1279	21,20254683
1399	21,50266362
1506	21,49276766
1926	21,73752194
2004	21,78467308
2144	21,80075694
2644	21,84429495
3064	22,05291079

Table 5 : Overload Gradient Values

Depth (m)	**Pore Pressure Gradient (lb/gal)**
290	16,72184063
1015	11,24228681
1279	9,133321552
1399	9,625845512
1506	10,07712012
1926	10,05312841
2004	8,600001671
2144	12,27786966
2644	12,2899998
3064	6,514059611

Table 6: Pore Pressure Gradient Values

Following is the distribution graph of the values found for pore pressure gradient and overload gradient.

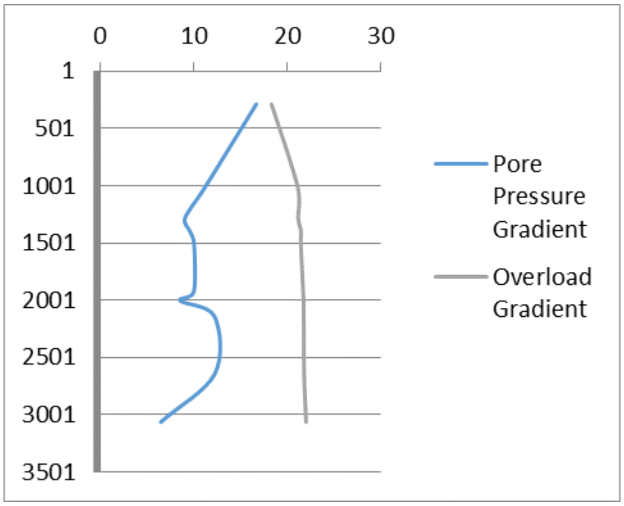

Figure 1: Graph of the distribution of the overload pressure gradients and well pore pressure.

From the estimation of the pore pressure gradient, it was possible to classify the pressure zones of the theoretical oil well of the Amazon Basin, Table 4.

Before the classification of the pore pressure gradient we verified the presence of 5 pressure zones in this theoretical well of the Amazon Basin. At the end of the predicted geopression estimation, a vertical well can be optimized in this basin with 4 phases, Figure 1, where the first phase is driven by the driver.

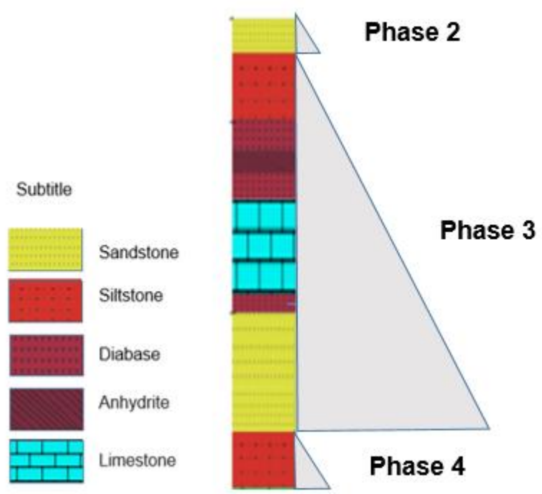

Figure 2: Proposal of expected number of phases in the well

Phase 2 crosses the Solimões formation and its predominant lithology is sandstone. Phase 3 crosses the Andirá, Nova Olinda, Itaituba, Monte Alegre, Faro and the three sills. And finally the phase 4 that will cross the formation Oriximiná composed mostly by siltstone.

Conclusions

In this work we observe that it is possible to estimate the geopressions for a developing basin that presents lack of available technical information, only with the cataloging of the history of technical scientific information.

The curve of the pore gradient refers to the critical analysis of five distinct zones according to figure 1 and table 4. Within the analysis the observed is the predominance of abnormally high zones.

The critical analysis of this information cooperates with scientific information published in the literature, where it refers to the physical characteristics of the lithology associated to the mechanisms generating high pressure, among them, geological age, In Situ voltages, overload effect, tectonism, fluid expansion, difference of density and migration of fluids, observed in history.

The analysis of the geopressions ratifies the phase optimization program of a well as can be seen in figure 2 with the distribution of phases within the formations of greater prominence in the pressure zones.

Acknowledgments

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References

ANP, Segunda Rodada de Licitações: Bacia do Amazonas, 2000.

ANP, Décima Rodada de Licitações: Bacia do Amazonas, 2009.

ANP. Décima Terceira Rodada de Licitações: Bacia do Amazonas, 2015.

NAZARÉ, C. P. P. Processamento sísmico CMP e CRS de dados sintéticos acústicos e elásticos representativos das Bacias Paleozóicas da região Amazônica / Dissertação (Mestrado em Geofísica) – Universidade Federal do Pará, Instituto de Geociências, Programa de PósGraduação em Geofísica, Belém, 2007.

ROCHA, L.A.S.; AZEVEDO, C.T. Projeto de Poços de Petróleo: Geopressões e assentamento de colunas de reestimento. Rio de Janeiro: Interciência: Petrobrás, 2009

THOMAS, J. E. Fundamentos de engenharia de petróleo. Rio de Janeiro: Interciência:2011