Pore Pressure Prediction and Distribution in Arthit Field, North Malay Basin, Gulf of Thailand

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Abstract

One of the major challenges in drilling wells for the exploration and development of hydrocarbon reservoirs is to understand the variability and distribution of fluid pressure in the subsurface. In Arthit field, North Malay Basin, Gulf of Thailand, 18 exploration wells and 2D seismic which cover the overpressure zones were used to investigate pore pressure prediction methods and the distribution of overpressure in Block 15A and 16A. Sonic and density logs were used to estimate shale porosity as a tool to evaluate and observe abnormal pressure or overpressured intervals. The resistivity and sonic logs were able to recognize with good response these overpressured intervals by plotting of both logs with true vertical depth. The Eaton method was used to calculate pore pressure using sonic and resistivity logs. These results were compared with directly measured formation pressure (SRFT). The estimated pore pressure from sonic log data is better than computed from resistivity log. The overpressure distributions mainly increase from north-west to south-east in the 2C unit and north to south with minor north-west to south-east direction in the deeper 2B and 2A units in Arthit field.

Keywords: Overpressure, Under-compaction, Sonic log, Resistivity log

1. Introduction

One of the major challenges in drilling wells for the exploration and development of hydrocarbon reservoirs is to understand the variability and distribution of fluid pressure in the subsurface. Although normal formation pressure or hydrostatic pressure areas are most commonly drilled, there are also many wells drilled in high formation pressure or overpressure areas. In the Gulf of Thailand, Arthit field, North Malay Basin the overpressure areas have not been developed. The understanding of pore pressure both of normal pressure and overpressure distribution in the subsurface is very important for well design in terms of the safe and economic drilling of wells in overpressured formations.

This research focuses on the pore pressure prediction and distribution of overpressure in the subsurface by using sonic, resistivity, density log data and seismic data from the Arthit field in the Gulf of Thailand.

2. Methods

The main objective of this study of pore pressure prediction and distribution of overpressure in the Arthit field was to use well log data to investigate log character responses to overpressure and to predict pore pressure by calculation from sonic and resistivity logs. This is post-drilled pore pressure evaluation.

Pore pressure prediction or estimation can be observed based on detecting and quantifying the porosity anomaly associated with disequilibrium compaction. The estimated shale porosity is a tool to investigate and determine the overpressure zone. The shale porosity is calculated from the density log (Asquith and Gibson, 1982) and sonic log (Raymer et al., 1980). The shale resistivity and sonic are also able to detect overpressure zones and be used to quantify them. The calculation of pore pressure is based on Eaton's method (Eaton, 1975) that used deep resistivity and a sonic log to calculate or predict pore pressure.

The seismic was used to interpret faults and the top formations for lateral overpressure distribution in Arthit field. The pore pressure predictions from the well date were used for mapping distribution of overpressure in the 2C, 2B and 2A units with maximum and average estimated pore pressures calculated.

3. Results

3.1 Shale porosity estimation from Sonic and Density logs

The shale porosity was estimated from both sonic and density log data in 18 exploration wells of which 13 wells were overpressured and 5 wells normal pressured. The shale porosity estimates show a deviation from the normal trend and respond to the overpressured formation. For example, in Figure 1 it was possible to pick top overpressure at 1800m TVDSS in well A.

3.2 Sonic and Resistivity logs response to overpressure

The 13 overpressured wells show log response to overpressure of both resistivity and sonic. The sonic log in overpressured shale or claystone interval shows increase in transit time with increasing pore pressure. The porosity increase in overpressured shale or claystone intervals is also reflected by a decrease in resistivity. The log response to overpressure of both sonic and resistivity logs were used to compute pore pressure values by Eaton's method.

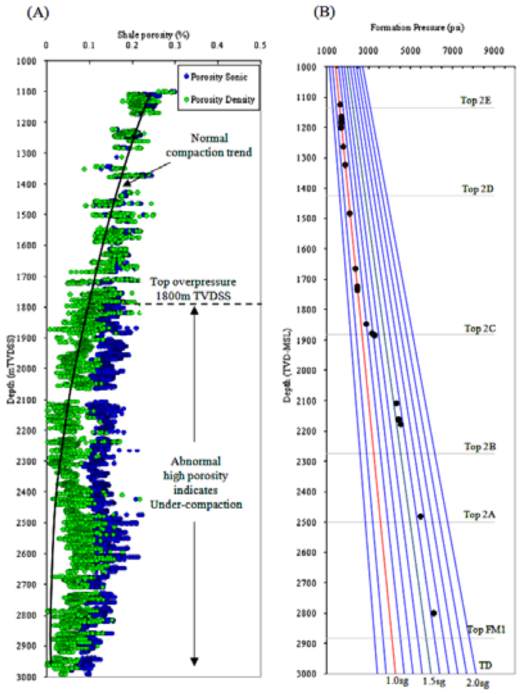


Figure 1. A well in block 16A. (A) The shale porosities estimated from sonic (blue) and density (green) log data. (B) The pressure - depth plot showing sediments overpressured below 1800m TVDSS from SRFT.

3.3 Pore pressure prediction

Thirteen wells were analyzed using wireline data because they are overpressured wells. The results of one of these wells are shown. The well B was drilled in block 15A with water depth 78 meters. The directly measured formation pressures and pore pressure prediction from wireline analysis in this study shows significant overpressure in the 2C, 2B and 2A units (Figure 2). The shale of those units shows the changing slowness of velocity in that interval and also the resisitivity log shows the changed reading of resistivity which decreases in that interval. The top overpressure or under-compaction is approximately 2080m TVDSS which is consistent with the top of 2C unit (FM2). Above 2080m TVDSS, shales show normal compaction sequence based on sonic and resistivity logs.

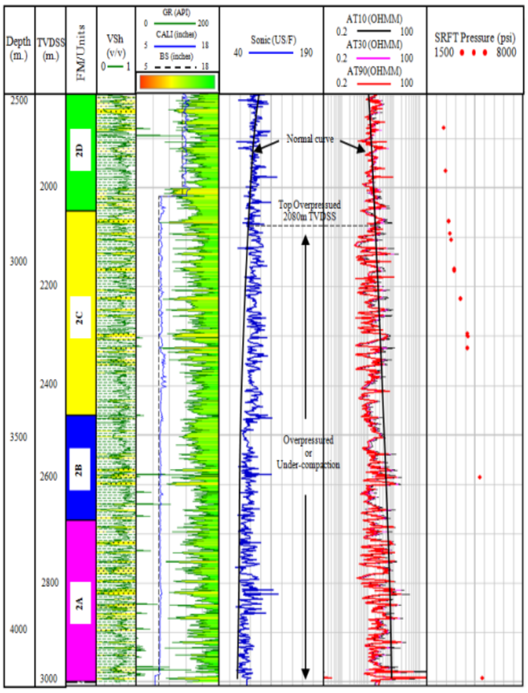
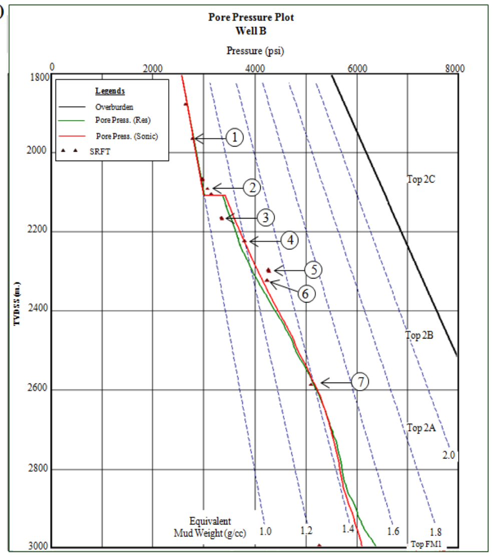


Figure 2. The directly measured formation pressure- depth plotted for well B with suite of wireline data as gamma ray, sonic, resistivity and also interpreted Vshale and Formation tops. The top overpressure was interpreted at 2080m TVDSS based on response to under-compaction of both sonic and resistivity logs.

The result of pore pressure prediction is shown in Figure 3 along with the comparison between 7 points with directly measured formation pressures (SRFT) versus calculated estimated pore pressure. The range of differences based on sonic log calculations is 5.90 to 248.72 psi with error 0.16 to 7.44% from SRFT. The range of differences based on resistivity log calculations is 38.83 to 313.10 psi with error 1.01 to 7.34 % from SRFT. The result of calculated pore pressure in normal pressure interval is close to SRFT but in overpressure interval is higher error compare to SRFT. The calculated pore pressure based on sonic log is more accurate than calculated pore pressure based on resistivity log.

(A)



B)

No.	Depth (mTVDSS)	SRFT (psi)	Sonic log			Resistivity log		
			Calculated (psi)	Difference (psi)	Error (%)	Calculated (psi)	Difference (psi)	Error (%)
1	1966.0	2768.62	2797.32	28.70	1.04	2807.45	38.83	1.40
2	2092.8	3065.50	2977.49	88.01	2.87	2992.68	72.82	2.38
3	2164.2	3340.75	3589.47	248.72	7.44	3522.53	181.78	5.44
4	2223.8	3796.65	3790.75	5.90	0.16	3683.73	112.92	2.97
5	2299.0	4264.31	4057.03	207.28	4.86	3951.21	313.10	7.34
6	2325.0	4230.31	4157.34	72.97	1.72	4060.84	169.47	4.01
7	2586.6	5100.13	5174.06	73.93	1.45	5151.55	51.42	1.01

Figure 3. Well B comparison between pore pressure prediction based on wireline analysis and SRFT. (A) The graph shows directly measured formation pressure- depth plotted and pore pressure prediction based on sonic and resistivity logs. (B) The table comparison 7 points between pore pressure prediction and SRFT. Also shown is the difference in psi and percentage of error.

3.4 The distribution of overpressure

The observation and study of log response to overpressure is matched with directly measured formation pressure. These confirm that the 2C, 2B and 2A units of formation 2 generate overpressure in this area. Consequently, the well log correlation, seismic interpretation and mapping of the distribution of overpressure focused on these 3 units.

Maps of overpressure were constructed based on estimated pore pressure from only sonic logs because both results of pore pressure (resistivity and sonic) were almost the same

There are two maps for each unit of formation 2 (2C, 2B & 2A), the average and maximum pore pressure prediction. The mapped distribution of overpressure for the maximum calculated pore pressure in the 2C unit, with the normally pressured wells in blue dots and overpressured in red dots, is shown in Figure 4 for example. The overpressure increases from north-west to south-east direction.

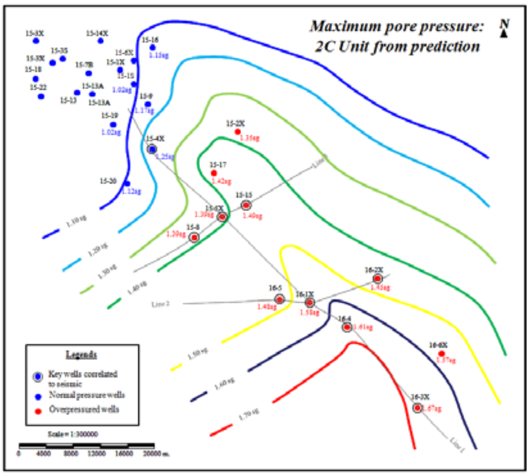


Figure 4. The mapped overpressure distribution of maximum calculated pore pressure in 2C unit. Normally pressured wells in blue dots and overpressured in red dots. The contour interval is 0.1 sg.

4. Discussion

Estimating shale porosity based on sonic and density logs is a useful tool to detect top of under-compaction or overpressure. In this study however, only sonic log responded to under-compaction in every well. In comparison, the density log was able to observe under-compaction in only a few wells because most likely the borehole was affected to reading measurements accurately. Consequently, the best detector of under-compaction is using estimated shale porosity from sonic log in the area.

For the sonic and resistivity log measurements of shale, every well detected under-compaction by plotting with depth and seeing the deviation from normal compaction trend. These logs are able to be used monitoring while drilling well in overpressure for casing shoe selection depth. Not only can these well logs be used for correlation to pick top overpressure zones but also the log response is very useful and confirmed overpressure zones in Arthit field for future development and exploration wells.

The comparison between pore pressure prediction using the sonic log or resistivity log showed the computed pore pressure from sonic log had a smaller error compared to SRFT measurements compared to data computed from resistivity log. Consequently, the estimated pore pressure from sonic log data is better than computed from resistivity log.

The overpressure distributions mainly increase from north-west to south-east direction for 2C unit and north to south with minor north-west to south-east direction for 2B and 2A units. Understanding this distribution might be useful for well planning of exploration or development well in this area. However, pore pressure model could be more accurate if we have more wells drilled in overpressure areas.

5. Conclusions

The overpressures are observed in 2C, 2B and 2A units with increases toward the mainly south-east direction in the middle of Block 15A to 16A, based on estimated pore pressure with SRFT calibration of maximum and average pore pressure for each unit.

The overpressures are mainly generated by disequilibrium compaction or under-compaction due to rapid subsidence which increases toward the south-east direction. On the well logs the overpressures in Arthit field exhibited anomalously increasing transit time and decreasing resistivity in shale intervals with volume of shale more than 80%.

The recognized under-compaction or normal compaction tool is shale porosity estimated from sonic log which had a good response to under-compaction in this area. Estimated porosity from density log was unable to detect under-compaction in most wells.

Using Eaton's method of predicting overpressure, the estimated pore pressures computed from sonic log were more accurate than those computed from resistivity log when compared to the SRFT pressure data.

The usefulness of this pore pressure prediction based on wireline or LWD data is to be able to estimate pore pressure in overpressure area without formation pressure testing or incomplete logging runs due to trouble on drilling operation.

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7. References

Asquith, G. B., and C. R. Gibson, 1982, Basic well log analysis for geologists: Tulsa, AAPG Methods in Exploration Services 3, 216 p.

Eaton, B. A., 1975, The Equation for Geopressure Prediction from Well Logs: Society of Petroleum Engineers 50th Annual Fall Meeting Proceeding, SPE 5544, 11 p.

Raymer, L. L., E. R. Hunt, and J. S. Gardner, 1980, An improved sonic transit time- to-porosity transform: Society of Professional Wireline Log Analysts 21st Annual Logging Symposium, 13 p.

Wyllie, M. R. J., A. R. Gregory, and L. W. Gardner, 1956, Elastic wave velocities in heterogeneous and porous media: Geophysics, v. 21, p. 41–70.