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Wireline logs vs. drilling events: Which one to believe in implying subsurface pressure?

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ABSTRACT As generally known, subsurface pressure can be implied using both wireline logs and drilling events. However, there may be a case where wireline logs and drilling events do not indicate the same subsurface pressure. Data from four vertical wells located in the South Sumatra Basin, Indonesia, were analyzed as a case study. Two wells, Wells A and D, encountered high overpressured zones, confirmed by drilling events and wireline logs data. The two others, Wells B and C, only encountered low overpressured zones, inferred by the relatively low mudweight used during the drilling. However, the wireline logs of Wells B and C show a reversal as Wells A and D. There are two hypotheses to explain the condition in Wells B and C. First, the wireline logs reversal is due to shallow carbonate cementation. Second, Wells B and C were drilled in an unintentional underbalanced condition. The method used includes XRD, SEM, and titration analysis. The results show that the first hypothesis is false, while the second is true. It may be due to some missing information related to drilling events in the final well reports of Wells B and C.

INTRODUCTION

Subsurface pressure anomaly, i.e., overpressure, can cause problems during the drilling. Lumpur Sidoarjo (LUSI) in the East Java Basin is the best example in Indonesia of how serious the problem can be. The subsurface pressure can be measured directly using pressure instruments such as Repeat Formation Tester (RFT) and Modular Formation Dynamic Tester (MDT) or indirectly based on wireline logs, mudweight, or drilling events like kick and gas while drilling.

Deviated sonic and resistivity logs from the normal compaction trend in a certain depth interval below the surface commonly indicate an overpressured zone. The presence of drilling events, such as a significant increase of mudweight, kick, and increasing gas content, can also indicate the overpressure condition. However, there may be a case where wireline logs imply an overpressure condition, but the drilling events do not. If so, which one implies the actual subsurface pressure becomes a question. This study aimed to analyze which data is more reliable in indicating the actual subsurface pressure in that case.

Wireline logs and drilling events data from four vertical wells located in the South Sumatra Basin, Indonesia, were analyzed as a case study. There are overpressured zones in the deeper parts of this basin, with the presence of both disequilibrium compaction and unloading mechanisms from the wireline logs (Ramdhan et al., 2018a; Syukri et al., 2019). Two of the wells analyzed in this study encountered high overpressured zones, confirmed by the drilling events and wireline logs data. The two others had low overpressured zones only, as inferred by the relatively low mudweight used during the drilling.

Well A (Figure 1a) is an example of wells that encountered a high overpressured zone. The sonic and resistivity logs of this well show an apparent reversal in the high overpressured zone. This well did not encounter significant problems during the drilling and can penetrate to the total depth (TD) because it was drilled with a proper mudweight. In comparison, Well B (Figure 1b) shows a similar sonic and resistivity logs reversal to Well A. It can also penetrate to the TD as Well A.

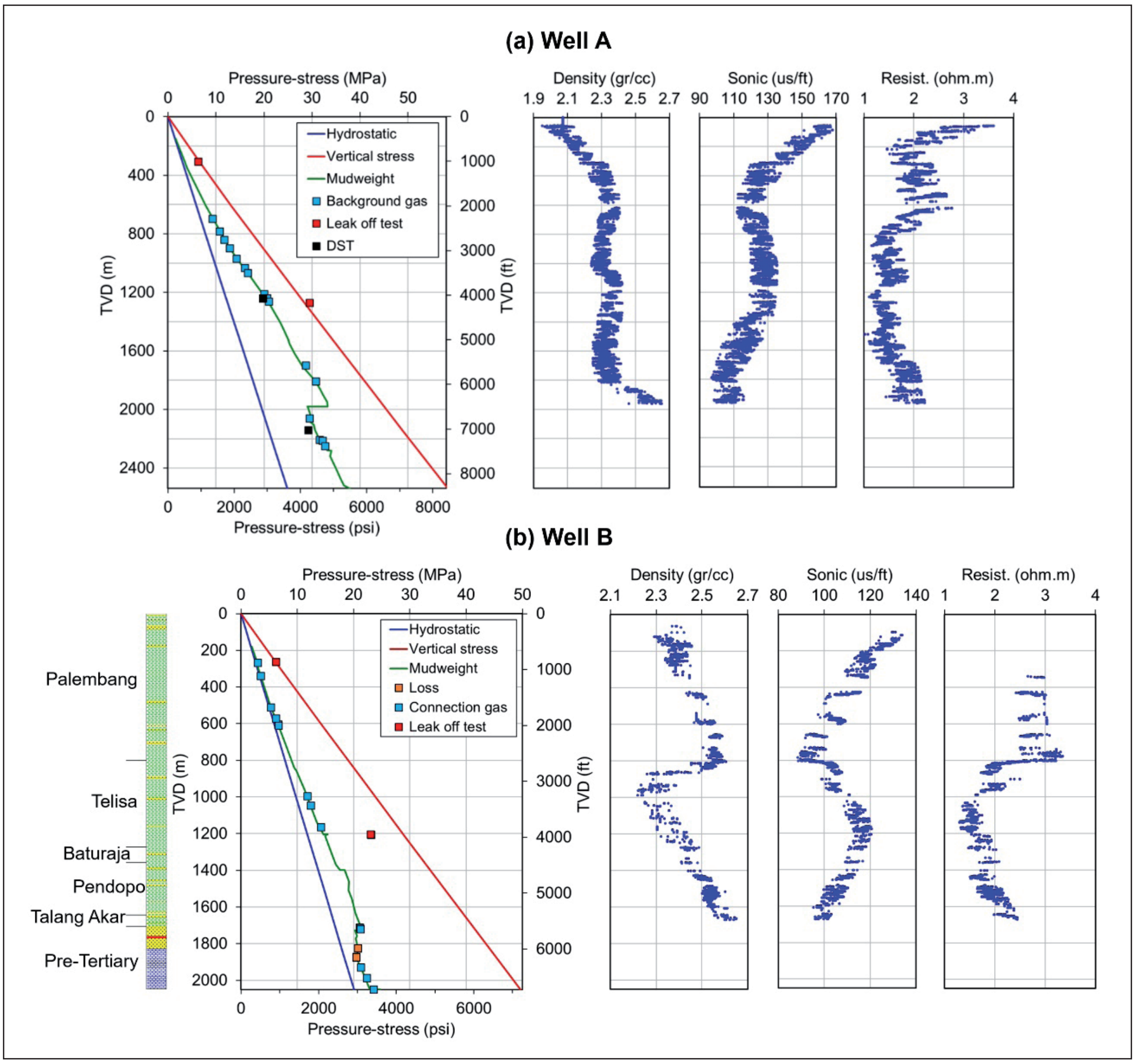

Figure 1. The comparison of the wireline logs in shale sections and the drilling events in Wells A and B.

However, the mudweight used during the drilling is significantly lower (up to ~three ppg lower) than the mudweight used in Well A. It leads to two hypotheses. First, the sonic and resistivity logs reversal in Well B is due to shallow carbonate cementation, as discussed by Eberli et al. (2003), and second, Well B was drilled in an unintentional underbalanced condition. Both hypotheses can result in a low magnitude of overpressure in the log reversal section. These are two hypotheses that were tested in this study.

Meanwhile, Wells C and D in the neighboring area have similar density, sonic, and resistivity logs responses as Well B, as shown later. Both Wells C and D were drilled using relatively low mudweight. These wells were used as a comparison in the analysis of Wells A and B in this study.

REGIONAL GEOLOGY

The physiography of the South Sumatra Basin can be divided into three sub-basins, i.e., the South Palembang Sub-Basin, the Central Palembang Sub-Basin, and the Jambi Sub-Basin, as shown in Figure 2a. The sedimentation of this basin began in the Early Eocene (Pertamina BPPKA, 1997). It mainly consists of Paleogene-Neogen sediments deposited above the Pre-Tertiary metamorphic and igneous basement (Figure 2b).

METHODS

The method used in this study includes mineralogical analysis using X-Ray Diffraction (XRD) and Scanning Electron Microscope (SEM), and titration analysis of the water from the XRD sample preparation. These laboratory works were carried out in the Hydrogeology and Hydrogeochemistry Laboratory in ITB. They were analyzed to test the first hypothesis related to shallow carbonate cementation that might explain the condition in Well B.

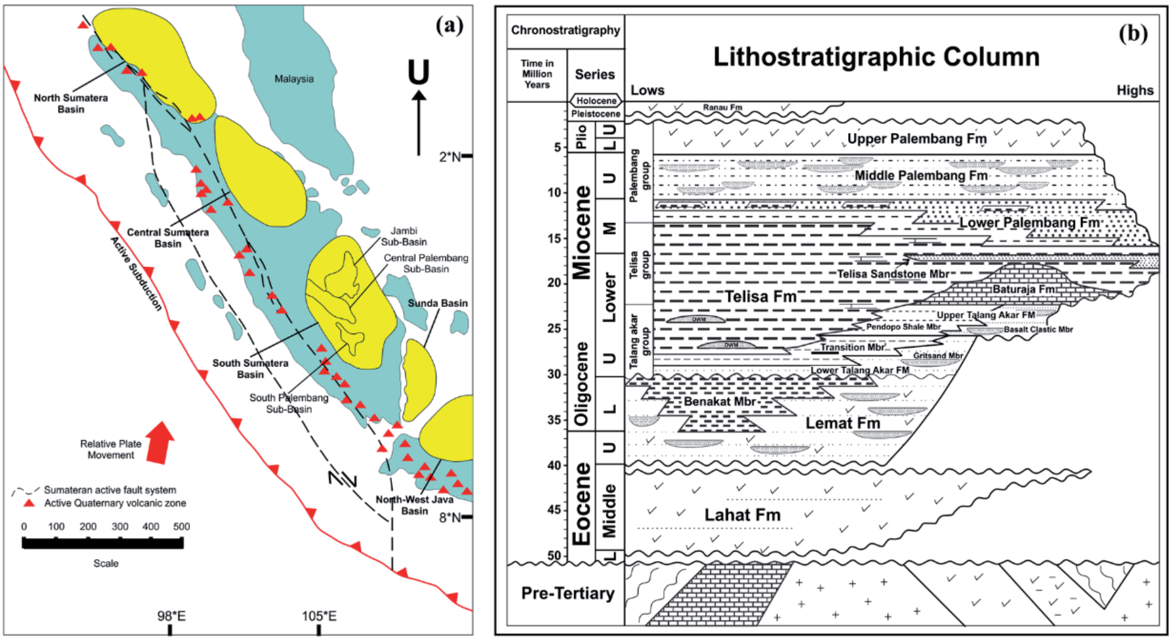

Figure 2. (a) The location of South Sumatra Basin according to Heidrick and Aulia (1993), and (b) The stratigraphy of the basin (after Kamal et al., 2008).

The XRD analysis verifies the percentage of carbonate mineral composition in Wells A and B cutting samples. At the same time, the SEM analysis is useful for confirming the presence of carbonate minerals in the cutting samples. Considering the possibility of diluted carbonate during the XRD sample preparation, the titration analysis of water from the sample preparation was conducted to obtain the bicarbonate concentration in the water samples.

The second hypothesis related to the unintentional underbalanced drilling condition was assessed based on the information from the final well report of Well B. In addition, the other data from the neighboring area, Wells C and D, was also used as a comparison. Well C has a similar characteristic to Well B, which also shows a strong wireline log reversal section while using a low mudweight during the drilling.

The depth of the samples for XRD and titration analyses is shown in Table 1. The equations that relate the pressure-density units used in this study are as follows:

$$\text{Mudweight in ppg} = \text{pressure in psi} / 0.052 / \text{depth} \quad (1)$$

$$\text{Mudweight in ppg} = \text{pressure in MPa} \times 145.038 / 0.052 / \text{depth} \quad (2)$$

$$\text{Mudweight in ppg} = \text{density in gr/cc} \times 8.33 \quad (3)$$

In addition, the wireline logs used in this study are all in the shale section. The shale/non-shale lithologies were differentiated based on the gamma-ray cut-off, as shown in Figure 3.

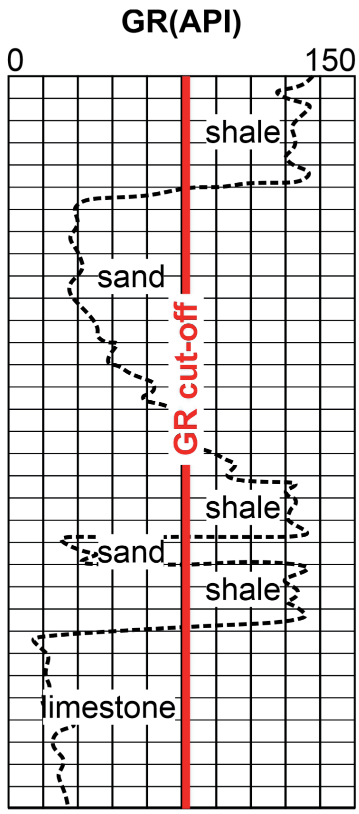

Figure 3. Schematic of shale and non-shale determination using gamma-ray (GR) cut-off.

Table 1. The depth of samples for XRD and titration analysis.

Sample	XRD		Titration
	Well A	Well B	Well B
	Depth (m)	Depth (m)	Depth (m)
1	90	145	230
2	140	230	530
3	260	530	675
4	270	675	805
5	365	805	1095
6	445	1095	1270
7	565	1270	1445
8	745	1445	1740
9	1020	1740	1945
10	1255	1945	2155
11	1515	2155	
12	1675	2394	
13	1845		
14	1910		

RESULTS AND DISCUSSION

The XRD analysis result of the samples from Wells A and B is shown in Figure 4. It shows that the carbonate percentages in both wells are minor compared to the other minerals, i.e., less than 5% of the bulk composition. Clay minerals (kaolinite and illite) are the most dominant minerals in both wells. The SEM analysis result of the samples from Well B also confirms the absence of carbonate minerals, as shown in Figure 5.

Table 2 shows the bicarbonate concentrations from titration analysis results of water from ten samples in Well B. The result shows that the bicarbonate concentrations in the water are relatively low, ranging from 36 to 312 ppm. The results confirm the low carbonate concentration in samples, which eliminates the first hypothesis. Thus, the next step is testing the second hypothesis.

From the comparison of Well B's sonic and resistivity logs with the pore pressure, sonic and resistivity logs of Well A, it seems that the mudweight used in Well B should be up to three ppg higher than those used during the drilling (red dashed line in Figure 6). The three ppg discrepancy should have caused drilling problems such as kicks, intensive caving, high gas content, or tight hole. However, based on the final well report, Well B was successfully drilled to the targetted total depth (TD) without any significant problems reported.

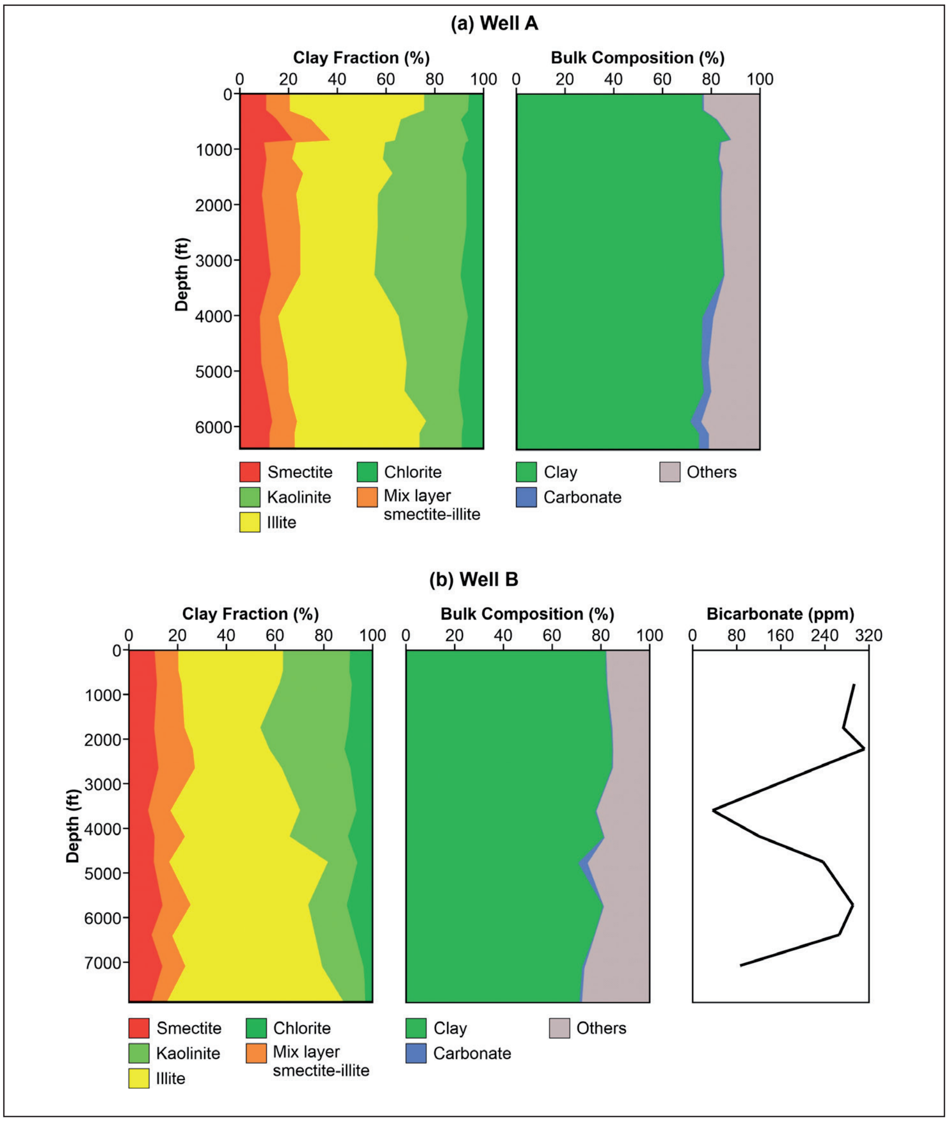

Figure 4. The mineralogy comparison of Wells A and B from XRD analysis results. On the right side is the bicarbonate concentration of the water from the XRD preparation of Well B samples.

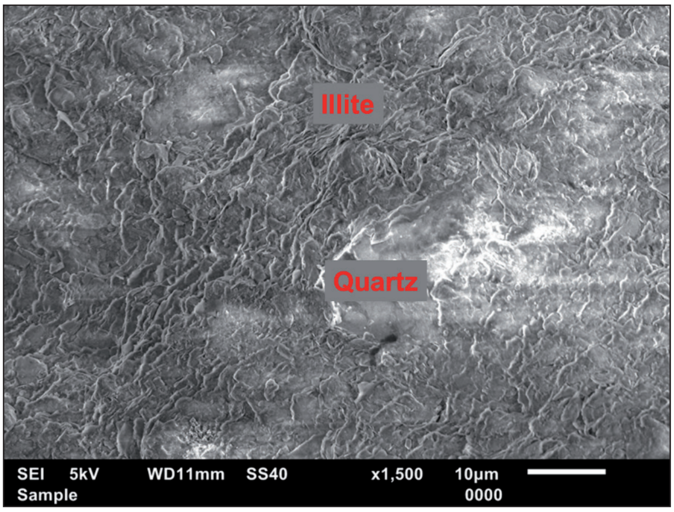

Figure 5. The SEM analysis result shows the absence of carbonate minerals in Well B.

Table 2. The titration analysis result of the water from the XRD preparation of Well B samples.

Samples	Bicarbonate Concentrations (ppm)	Samples	Bicarbonate Concentrations (ppm)
1	293	6	120
2	273	7	237
3	312	8	291
4	225	9	266
5	36	10	86

Figure 7 shows the comparison of density, sonic, and resistivity logs of Wells C and D in the neighboring area. The Well C density, sonic, and resistivity logs have the same responses as wireline logs in Well B, which also deviate from the normal compaction trend. The mudweight used during the drilling is also relatively low, with no significant drilling problems reported in the final well report of this well.

Well D is located adjacent to Well C, and it has similar wireline log responses as Well C (Figure 7). The drilling of these two wells used the same mudweight. Several drilling problems appeared when the data collected and reported from Well C was used as a reference for drilling Well D. These problems include kick, caving, sloughing shale, tight hole, high gas content, pipe stuck, and more. Especially when the drilling reached the depth of the reversal logs section, starting at ~1,100 m. These drilling problems indicate that the mudweight used in Well D drilling is lower than the pore

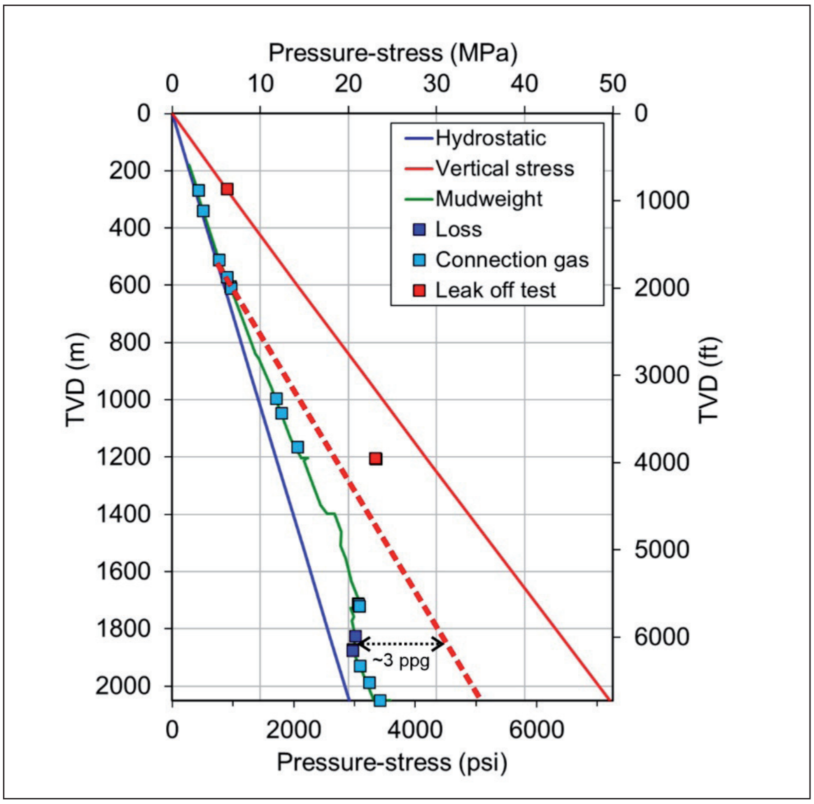

Figure 6. The estimated mudweight (red dashed line) that should have been used in Well B.

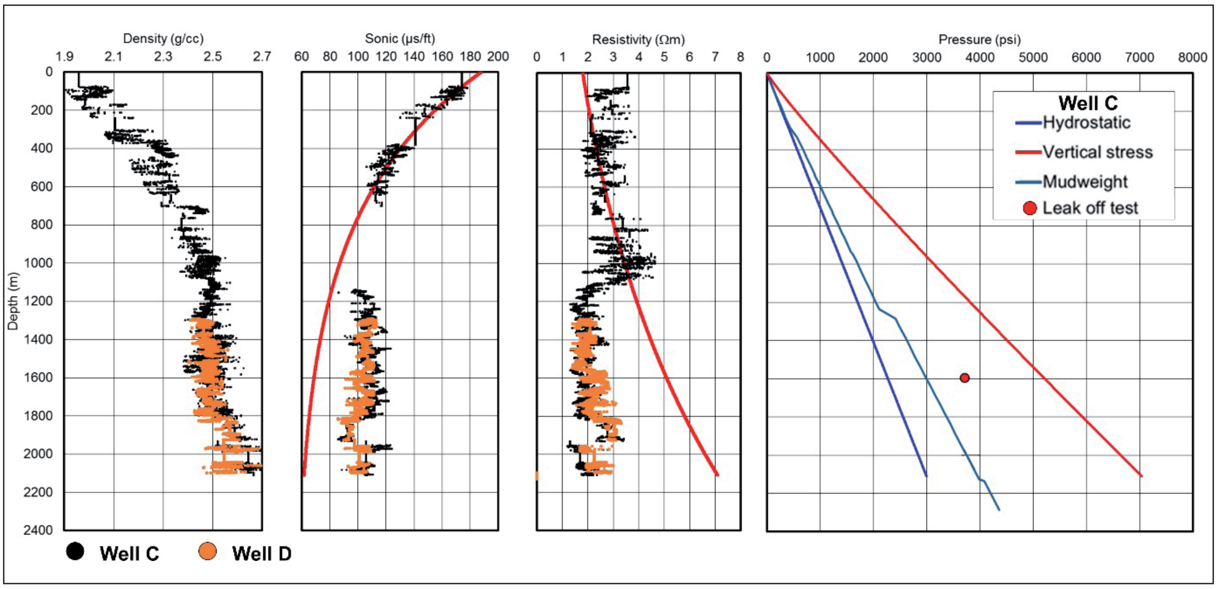

Figure 7. The comparison of wireline logs in shale sections between Well C and D.

pressure. The conclusion is that this well drilling condition is unintentionally underbalanced. It also shows that Well C was actually drilled under a similar condition. However, the information related to this, e.g., problems encountered during the drilling, was not provided in the final well report of Well C.

These results suggest that the second hypothesis is the possible explanation for the case in Well B. It can be sure that the condition as in this hypothesis happened in Well B, i.e., drilled in an unintentional underbalanced condition. However, the question is why the possible drilling events/problems, such as kick, intensive caving, and pipe stuck, were not recorded in the final well report. It suggests that wireline logs as more reliable in implying the subsurface pressure than drilling events written in the final well report, especially when the final well report does not imply a similar pore pressure and drilling events/problems encountered during the drilling.

Moreover, there are some sand sections in the generalized lithologic column of Well B (Figure 1b). If the drilling condition was unintentionally underbalanced, it should have encountered some kicks during the sand section drilling. However, this problem was absent. It is probably due to the presence of lateral reservoir drainage, as discussed in Ramdhan et al. (2018b) and Syaiful et al. (2020), that should be analyzed comprehensively in further studies.

CONCLUSIONS

As discussed in the result, the possible explanation for the condition in Well B was drilling in an unintentional underbalanced condition. The analysis results eliminate the shallow carbonate cementation as the possible explanation of the wireline logs reversal, the use of low mudweight, and the absence of any major drilling problems encountered. Both wireline logs and drilling events can be used to imply the subsurface pressure. In the case of Wells C and D, it was clear that there is some missing information related to drilling events in the final well report of Well C, e.g., drilling problems such as pipe stuck and caving.

As happened in Well D, missing information on any reference well final well report can lead to a serious problem when drilling a new well. Checking and comparing the final well report with the daily drilling report, from a practical view, can be a solution to prevent any missing information, even though it may not be available under certain conditions. Moreover, this study also shows that wireline logs are more reliable in implying subsurface pressure and designing a drilling program than drilling events in the final well report, especially when the information provided in the final well report of the reference well do not infer the same possible pore pressure and drilling events/ problems as the wireline logs do.

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