



Pore Pressure Estimation Using Sonic Log and Eaton Method: Well YCG-P2A Case Study

Yolanda Tryana Sitorus*
Institut Teknologi Sumatera, Indonesia

Cendikia Laisatara
Institut Teknologi Sumatera, Indonesia

Gabe Bagus Arthantha
Institut Teknologi Sumatera, Indonesia

Pasu Pradasari Purba
Institut Teknologi Sumatera, Indonesia

Muhammad Aqil Adib
Institut Teknologi Sumatera, Indonesia

Muhammad Rasyd Ridho
Institut Teknologi Sumatera, Indonesia

Devano Ramadhan
Institut Teknologi Sumatera, Indonesia

***Corresponding author:**

Yolanda Tryana Sitorus,
Institut Teknologi Sumatera, Indonesia.
yolanda.122480045@student.itera.ac.id

Article Info :

Article history:

Received: Mei 3, 2026
Revised: Mei 10, 2026
Accepted: Mei 29, 2026
Published : Mei 30, 2026

Keywords:

Keywords 1: Pore Pressure
Keywords 2: Eaton Method
Keywords 3: Pressure Regime.

Abstract

Pore pressure prediction is an essential aspect of drilling planning to minimize the risks of kick, blowout, and lost circulation during drilling operations. This study focuses on estimating the pore pressure profile of Well YCG-P2A using sonic log data processed with the Eaton method. Sonic log responses from stable shale intervals were utilized to establish the Normal Compaction Trend (NCT), which served as the basis for pore pressure calculation within the depth range of 1,000–6,470 ft. Overburden stress was derived from density log integration, while hydrostatic pressure was calculated using a standard formation fluid gradient. The Eaton equation was then applied to generate a continuous pore pressure profile throughout the analyzed interval. The results show that pore pressure generally follows the hydrostatic trend, indicating predominantly normal pressure conditions across most of the well section. However, a localized decrease below hydrostatic pressure is observed at depths of approximately 3,500–3,700 ft, suggesting a possible underpressure anomaly. In contrast, pore pressure gradually increases above hydrostatic conditions within the 5,300–6,200 ft interval, indicating the presence of mild-to-moderate overpressure likely associated with undercompaction and restricted pore fluid expulsion. The Eaton method demonstrated good capability in identifying pressure variations and potential anomalous zones in Well YCG-P2A, although several intervals required careful interpretation due to log quality limitations and signal noise. Further calibration using direct formation pressure measurements, such as core analysis, Repeat Formation Tester (RFT), Modular Dynamics Tester (MDT), or Drill Stem Test (DST), is recommended to improve the reliability of the estimation results. Overall, this study provides a useful reference for mud weight determination, casing design, and drilling planning in Well YCG-P2A and adjacent wells within the same formation.

INTRODUCTION

Pore pressure prediction is a fundamental aspect of drilling planning and operations for oil and gas wells. The accuracy of formation pressure estimation directly influences casing design, drilling mud weight determination, and the mitigation of operational risks such as kick, blowout, lost circulation, and stuck pipe (Fauzan et al., 2024). Errors in determining the pressure regime can lead to well failure, increased non-productive time (NPT) costs, and threats to worker safety (Susanty & Wardana, 2021). Therefore, identifying whether a formation is under normal pressure, overpressure, or underpressure conditions is a crucial step prior to drilling.

Conventionally, pore pressure can be obtained through direct measurements using tools such as the Drill Stem Test (DST) or Repeat Formation Tester (RFT). However, these methods only provide data at specific depth points due to high operational costs and time constraints (Susanty & Wardana, 2021). To obtain a continuous pressure profile along the wellbore, indirect approaches based on well logging data have become the most effective alternative. One of the most widely used empirical methods in the industry is the Eaton method, which utilizes sonic log data. The sonic log records acoustic wave travel time, which is closely correlated with rock compaction levels. Under normal compaction conditions, travel time decreases systematically with increasing depth (Reza Syaputra et al., 2017). Deviations from this trend indicate changes in the pressure regime, signaling either overpressure or underpressure conditions (Salfigo et al., 2024).

Several previous studies have confirmed the reliability of the Eaton method in predicting pore pressure. Reza Syaputra et al. (2017) successfully applied the Eaton method based on interval velocity data from seismic and well logs to optimize mud and casing design in the South Sumatra Basin, while emphasizing the importance of local parameter calibration and accurate Normal Compaction Trend (NCT) determination. Muhazzib et al. (2017) demonstrated that the reliability of empirical methods heavily depends on selecting stable shale intervals and understanding overpressure mechanisms, such as loading due to high sedimentation rates. Conversely, Susanty & Wardana (2021) highlighted the limitations of conventional empirical methods, particularly when facing lithological variations and uncertainties in NCT determination, which sometimes require artificial intelligence-based approaches as alternative solutions. Despite these limitations, the Eaton method combined with sonic logs remains an industry standard due to its simplicity, ease of application, and ability to provide a rapid overview of formation pressure regimes, provided that data calibration and corrections are properly executed.

Based on this background, this study aims to estimate the pore pressure profile of Well YCG-P2A using sonic log data and the Eaton method. This research specifically identifies the onset depth of abnormal pressure, determines the pressure regime (normal, overpressure, or underpressure), and evaluates the effectiveness of the Eaton method under local geological conditions and well log quality. The findings are expected to provide practical guidance for determining the mud weight window and safe drilling design, as well as serve as an applicable reference for development wells in the same formation.

METHOD

This study employs a quantitative analytical-empirical approach to estimate the pore pressure profile of Well YCG-P2A using sonic log data and the Eaton method. This design was selected because it enables quantification of sonic log response deviations from normal compaction conditions, allowing objective interpretation for formation pressure regime identification. The research object consists of well logging data specifically sonic (DT) and density (RHOB) logs obtained from Well YCG-P2A over the depth interval of 1,000–6,470 ft. Due to data availability constraints, the analysis was limited to this interval, which exhibits sufficient data quality for reliable interpretation.

Data processing was conducted systematically, beginning with data preparation and filtering. Subsequently, the Normal Compaction Trend (NCT) was constructed through exponential regression on the normally pressured zone, serving as a reference baseline to quantify compaction deviations. Hydrostatic pressure was calculated based on formation fluid density using the equation $P_h = 0.052 \times \rho_{fluida} \times Z$, where ρ_{fluida} represents fluid density in ppg and Z is depth in feet (Nurdin, 2016). Overburden pressure was computed by integrating bulk density from the RHOB log following the density method: $P_h = 0.052 \times \rho_{bulk} \times Z$ (Zunandar, 2023).

Pore pressure was then estimated continuously using the empirical Eaton equation with a locally calibrated exponent, which relates overburden pressure, hydrostatic pressure, and the ratio between transit time on the NCT and measured transit time: $P_p = \sigma_v - (\sigma_v - P_h) \left(\frac{DT}{NCT} \right)^3$,

$NCT = (\Delta t_0 - \Delta t_m) e^{-bz} + \Delta t_m$ where m is the Eaton exponent adjusted for local conditions (Eaton, 1999; Ziaie et al., 2023). All analyses were performed using MATLAB computational software, where each sonic log deviation from the NCT was transformed into pore pressure values and visualized in depth-pressure plots for anomaly onset identification.

This approach integrates rock geomechanics principles and drilling operational parameters, aligning with the multidisciplinary orientation that emphasizes safety, cost efficiency, and technical

risk mitigation in the field.

RESULTS AND DISCUSSION

This section presents the pore pressure estimation results for Well YCG-P2A using the sonic log-based Eaton method, followed by their interpretation and operational implications. The findings are organized to first display data characteristics and hydrostatic pressure analysis, then present the NCT construction and pore pressure profile, and finally compare estimated pore pressure against hydrostatic conditions to identify pressure regimes. Key results are summarized in tables and figures referenced throughout the narrative to support clarity and reproducibility.

Data Characteristics and Hydrostatic Pressure Baseline

Initial evaluation focused on the sonic (DT) and density (RHOB) logs, which serve as the primary inputs for the Eaton pore pressure estimation method. As shown in Figure 1, the sonic log records variations in acoustic travel time that are sensitive to rock compaction changes, while the density log reflects bulk density trends associated with burial and sediment compaction processes. In general, the DT values decrease and RHOB values increase with depth, indicating a normal compaction trend caused by increasing overburden stress and progressive porosity reduction. These log responses provide important information regarding the mechanical behavior of subsurface formations and their relationship to pore fluid conditions.

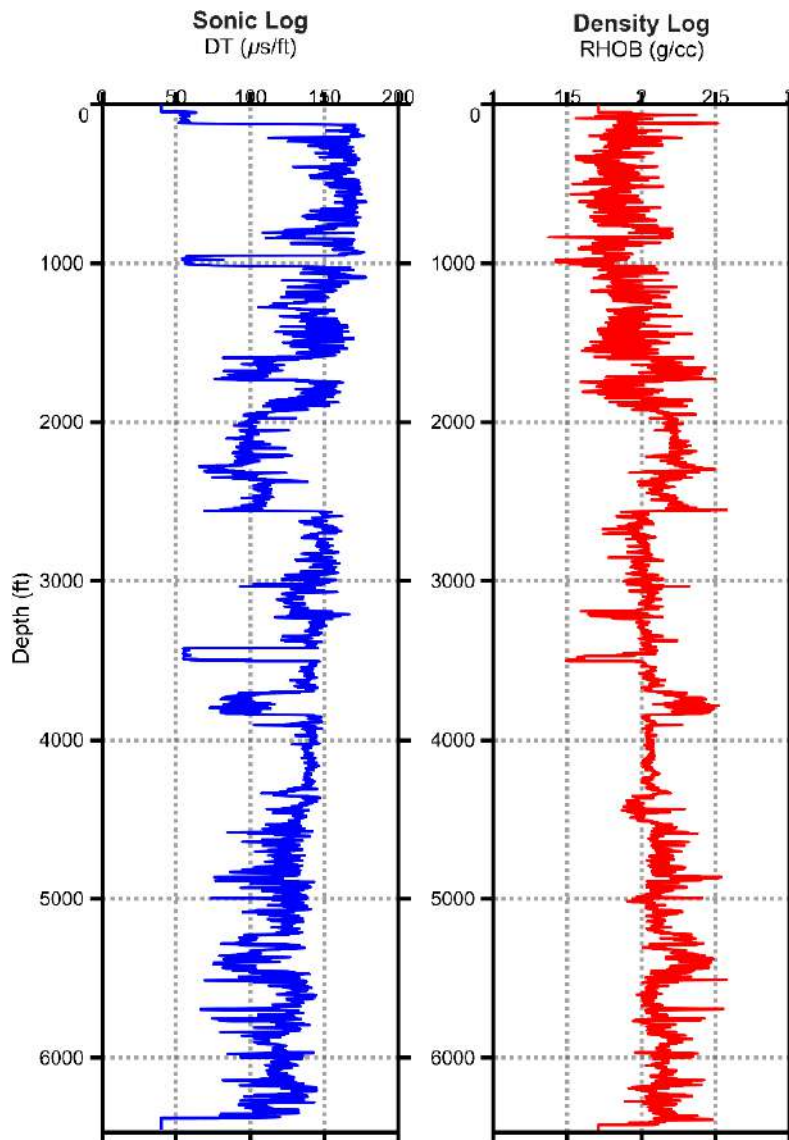


Figure 1 Sonic Log and Density Log

Both logs were filtered to select stable shale intervals for Normal Compaction Trend (NCT)

construction using gamma ray thresholds (>80 API) and porosity crossplot analysis to exclude sandstone and carbonate intercalations. The established NCT serves as the hydrostatic pressure baseline in the Eaton method. Deviations from this normal trend, particularly increases in DT values or reductions in RHOB values at certain depths, may indicate inhibited compaction related to abnormal pore pressure development. Therefore, the integration of sonic and density log characteristics is essential for identifying pressure anomalies and evaluating subsurface pore pressure distribution within the well.

Hydrostatic pressure, calculated using formation fluid density, serves as the baseline for identifying abnormal pressure zones within the subsurface formation. Figure 2 illustrates the hydrostatic pressure distribution with depth for Well Y. The hydrostatic pressure curve shows a consistent linear increase as depth increases, reflecting the normal behavior of a static fluid column under equilibrium conditions. This trend indicates that the pressure gradient is primarily controlled by the weight of the overlying formation fluids and remains relatively stable throughout the analyzed interval.

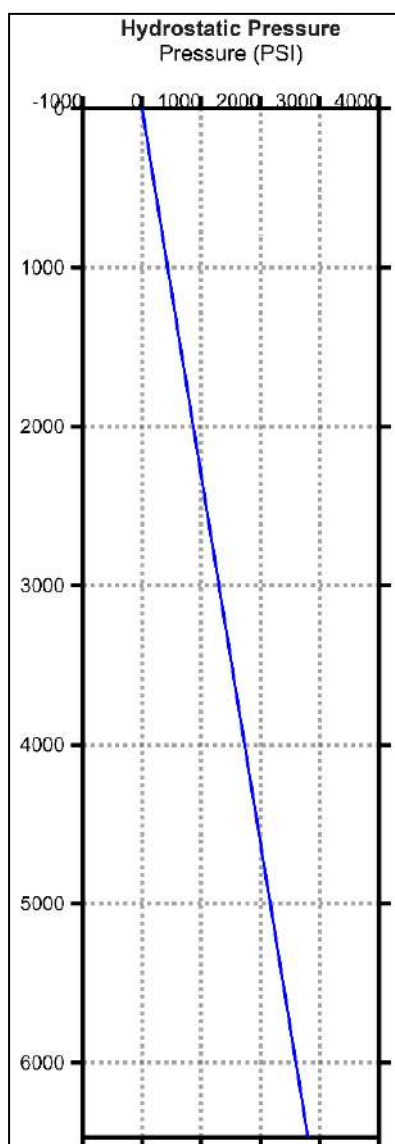


Figure 2 Hydrostatic Pressure

The absence of significant fluctuations or irregular deviations in the hydrostatic pressure profile confirms that the hydrostatic model provides a reliable reference for pore pressure evaluation using the Eaton method. In pore pressure analysis, this baseline is essential for distinguishing normal pressure conditions from abnormal pressure regimes such as overpressure or underpressure. Any substantial deviation of the estimated pore pressure curve from the hydrostatic trend may indicate changes in formation compaction, fluid retention, or lithological characteristics that influence subsurface pressure behavior. Therefore, the hydrostatic pressure profile establishes a fundamental framework for

interpreting pore pressure distribution and identifying potential pressure anomalies within the well.

Normal Compaction Trend Construction and Pore Pressure Estimation

The Normal Compaction Trend (NCT) represents the expected sonic log response under normally compacted shale conditions and serves as the primary reference for pore pressure estimation using the Eaton method. Figure 3 presents the relationship between the measured sonic log (DT) and the constructed NCT in the left track, along with the resulting pore pressure profile in the right track. In the shallow intervals, the measured DT values generally follow the NCT, indicating that the formations are experiencing normal compaction behavior. As depth increases, several intervals exhibit upward deviations of the sonic log from the NCT, reflecting higher acoustic travel times than expected under normal compaction conditions. These deviations suggest the presence of undercompacted shale intervals where pore fluids remain trapped within the formation, thereby reducing the effective stress and slowing the compaction process.

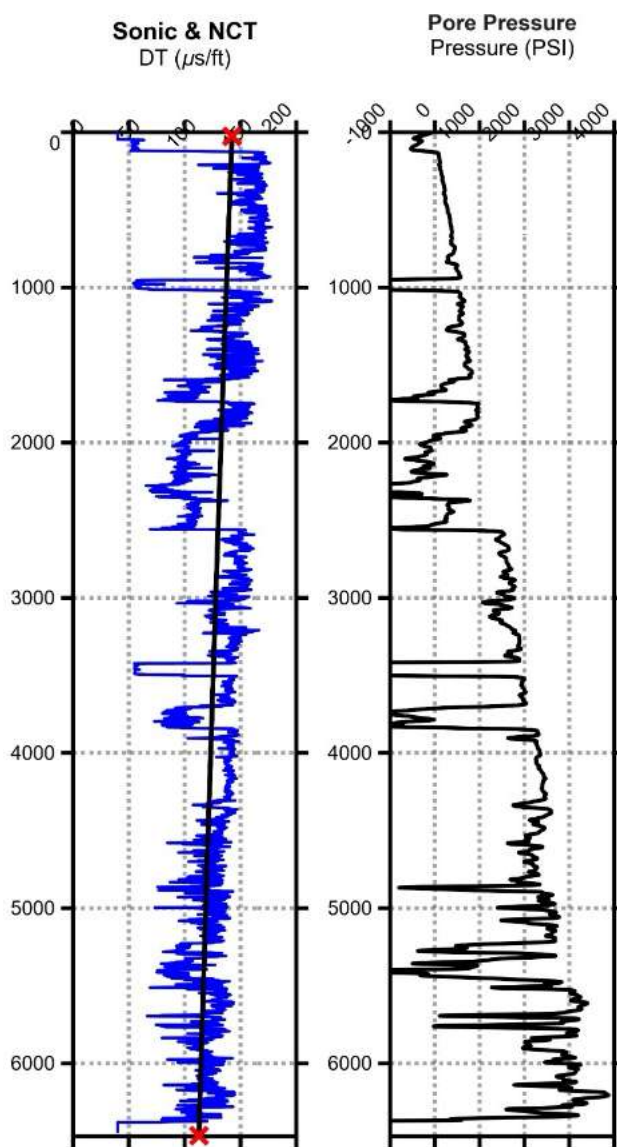


Figure 3 NCT and Pore Pressure

The pore pressure profile shown in the right track demonstrates that intervals with significant sonic log deviations correspond to elevated pore pressure values calculated using the Eaton method. The increase in pore pressure is particularly noticeable in the deeper sections, where the separation between the measured DT and the NCT becomes more pronounced. This relationship confirms that the Eaton method is highly sensitive to compaction anomalies reflected in sonic log responses. The observed pressure increases indicate the possible development of mild to moderate overpressure zones associated with fluid retention and incomplete sediment compaction. Therefore, the integration of sonic log deviation analysis and NCT construction provides an effective approach for identifying pore pressure

variations and evaluating subsurface pressure behavior within the well.

Comparative Analysis: Pore Pressure vs. Hydrostatic Conditions

Figure 4 presents the estimated pore pressure profile obtained from the Eaton method compared with the hydrostatic pressure baseline. The hydrostatic curve, shown as the dashed blue line, represents the normal pressure gradient expected under equilibrium fluid conditions, while the black curve illustrates the calculated pore pressure distribution throughout the well interval. In general, the pore pressure profile follows the hydrostatic trend, indicating that most formations within the well remain under normal pressure conditions. The relatively consistent relationship between the two curves suggests that compaction processes are generally occurring normally, with pore fluids being expelled efficiently during burial and sediment loading.

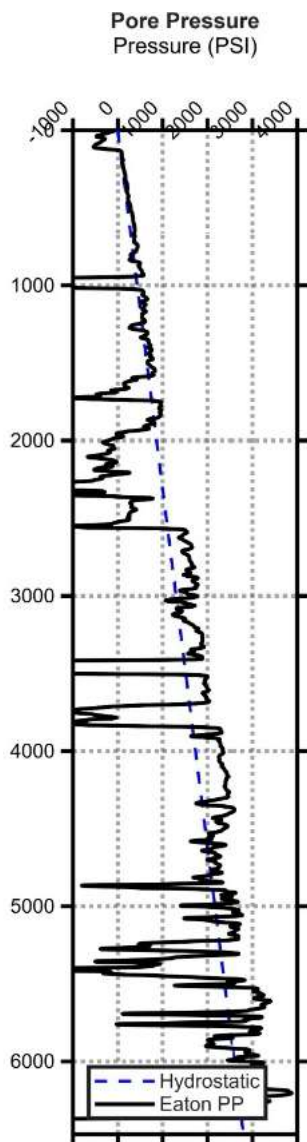


Figure 4 Hydrostatic and Pore Pressure

Several localized pressure anomalies, however, can be observed at specific depth intervals. From the surface to approximately 3,500 ft, the pore pressure curve remains close to the hydrostatic baseline, confirming predominantly normal pressure conditions with only minor local fluctuations. Between approximately 3,500–3,700 ft, the pore pressure profile exhibits a noticeable downward deviation below the hydrostatic trend, which may indicate localized underpressure or possible influences from lithological changes and log response variability. The pore pressure subsequently returns to near-hydrostatic conditions within the 4,000–5,300 ft interval, suggesting stable pressure behavior and normal compaction characteristics. In the deeper section, particularly between 5,300–6,200 ft, the pore pressure curve progressively rises above the hydrostatic baseline, indicating the development of mild-

to-moderate overpressure. This pressure increase is likely associated with undercompaction, reduced permeability, lithological variation, or restricted fluid expulsion that inhibits normal sediment compaction. Overall, the pore pressure profile demonstrates that the Eaton method effectively captures both normal and anomalous pressure regimes within the subsurface formation.

Tabel 1 Interpreted Pressure Regimes for Well YCG-P2A

No.	Depth Interval (ft)	Pressure Regime
1	1000-3500	Normal Pressure
2	3500-3700	Underpressure (Local)
3	4000-5300	Normal Pressure
4	5300-6200	Overpressure (Mild–Moderate)

Discussion: Implications for Drilling Design and Risk Mitigation

The identification of normal, underpressure, and overpressure intervals has direct operational implications. For the predominantly normal pressure sections (1,000–3,500 ft and 4,000–5,300 ft), mud weight can be maintained within the standard hydrostatic window (~8.33–8.6 ppg for formation water), balancing wellbore stability with minimal formation damage.

The local underpressure anomaly at 3,500–3,700 ft warrants caution: if confirmed, excessive mud weight could induce lost circulation or formation damage. Validation using additional logs (resistivity, caliper) or drilling events (fluid losses) is recommended before finalizing mud program decisions for this interval.

The mild-to-moderate overpressure indication at 5,300–6,200 ft represents the most critical finding. Elevated pore pressure increases the risk of kick or blowout if mud weight is insufficient. Based on the estimated pressure gradient in this interval, mud weight should be increased while remaining below the fracture gradient to avoid lost circulation. This interval may also benefit from additional casing string placement to isolate the overpressured zone, enhancing well control safety.

These findings align with previous studies emphasizing the importance of local calibration for Eaton method applications (Muhazzib et al., 2017; Reza Syaputra et al., 2017) The observed pressure anomalies likely reflect geological mechanisms such as disequilibrium compaction due to rapid sedimentation or lithological sealing, consistent with regional basin characteristics. However, the presence of data noise in certain intervals underscores the need for integration with direct pressure measurements (RFT/MDT) where available to improve prediction confidence.

From a multidisciplinary perspective, this study bridges geomechanical analysis with operational decision-making. The pore pressure profile not only informs technical drilling parameters but also supports risk management frameworks by identifying zones requiring enhanced monitoring or contingency planning. Future wells in the same formation can leverage these results to optimize mud programs and casing designs, potentially reducing non-productive time and improving overall drilling efficiency.

CONCLUSION

This study successfully estimated the pore pressure profile for Well YCG-P2A using the Eaton method and sonic log data, providing a continuous quantitative assessment of the subsurface pressure regime. The analysis revealed that while the well is predominantly characterized by normal hydrostatic conditions, significant deviations occur at specific intervals: a localized underpressure zone at 3,500–3,700 ft and a critical mild-to-moderate overpressure zone between 5,300 and 6,200 ft. These findings confirm that undercompaction is the primary driver for pressure anomalies in this formation.

Practically, the derived pressure profile serves as a high-fidelity guide for drilling engineers to optimize mud weight windows and casing seat selections, directly enhancing operational safety and reducing non-productive time (NPT). Academically, the integration of NCT-deviation analysis with the Eaton equation proves to be a robust approach for pressure prediction in complex sedimentary sequences. To further refine these results, future research should incorporate direct pressure measurements such as RFT or MDT to calibrate the Eaton exponent and investigate the influence of clay mineralogy on sonic log responses in the underpressured intervals.

REFERENCES

- Eaton, B. A. (1999). Fracture gradient prediction and its application in oilfield operations. *SPE Reprint Series*, 49, 88–95. <https://doi.org/10.2118/2163-pa>
- Fauzan, A., Firmansyah, Y., Mohamad, F., Yuniardi, Y., Gani, R. M. G., & Nursasono, D. (2024). *Pore Pressure Dan Fracture Gradient Pada Sumur AF-78, Cekungan Kutai, Formasi Balikpapan, Kalimantan Timur*. 8(3), 2141–2147.
- Muhazzib, Bahri, A. S., & Widodo, A. (2017). Prediksi Tekanan Pori Menggunakan Metode Kompresibilitas di Reservoir Karbonat, Studi Kasus : Lapangan MZ. *Jurnal Teknik ITS*, 6(2). <https://doi.org/10.12962/j23373539.v6i2.24019>
- Nurdin, D. M. (2016). *Tekanan Pori*. Institut teknologi Bandung.
- Reza Syaputra, M., Sapto Mulyatno, B., & Herdiana, Y. (2017). Pemodelan Prediksi Tekanan Pori Menggunakan Metode Eaton’S Berdasarkan Data Interval Velocity Pada Lapangan Hidrokarbon “Ertiga”, Cekungan Sumatera Selatan. *Jurnal Geofisika Eksplorasi*. <http://journal.eng.unila.ac.id/index.php/geo/article/view/1028/682>
- Salfigo, R. F., Firdaus, Amiruddin, Paingan, E. N., Risna, & Fatma. (2024). Prediksi Pore Pressure dan Fracture Gradient (PPFG) Pada Sumur Hsn menggunakan Pendekatan Sumur Rhn & Fgo Pada Lapangan Bunyu Cekungan Kutai. *PETROGAS: Journal of Energy and Technology*, 6(2), 1–10. <https://doi.org/10.58267/petrogas.v6i2.172>
- Susanty, M., & Wardana, R. S. (2021). Prediksi Tekanan Pori Berdasarkan Data Logging Sumur Menggunakan Deep Neural Network. *Petir: Jurnal Pengkajian Dan Penerapan Teknik Informatika*, 14(1), 81–89. <https://doi.org/10.33322/petir.v14i1.964>
- Ziaie, M., Fazelizadeh, M., & Ayatizadeh, A. (2023). Estimation of The Horizontal In-Situ Stress Magnitude and Azimuth Using Previous Drilling Data. *Ke Ai Advancing Research Evolving Science*, 9(3). <https://doi.org/10.1016/j.petlm.2023.02.006>
- Zunandar, K. (2023). *Evaluasi Mud Weight Berdasarkan Model Geomekanik 1D Dalam Upaya Menjaga Wellbore Stability Pada Sumur “VZF - 023” Lapangan “KHEZU.”* Universitas Pembangunan Nasional “Veteran” Yogyakarta.