

# SAND PRODUCTION RISK PREDICTION IN WEAKLY CONSOLIDATED FORMATIONS USING AN INTEGRATED GEOMECHANICAL APPROACH: A CASE STUDY FROM CUU LONG BASIN, OFFSHORE VIETNAM

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## Summary

Sand production during hydrocarbon extraction represents a critical operational challenge, particularly in weakly consolidated formations such as the Miocene sandstones of the Cuu Long basin, offshore Vietnam, leading to production losses, equipment damage, and potential well abandonment. Accurate prediction is essential for optimizing completion design and selecting suitable sand control.

This study presents a multi-index geomechanical approach for predicting sand production risk using five indicators: (1) sonic transit time (DTCO), (2) sand production index - BI, (3) Schlumberger sand production ratio - SR, (4) combined elastic modulus -  $E_c$ , and (5) unconfined compressive strength - UCS. These indices are derived from basic well logs (gamma-ray, sonic, and density) and calculated geomechanical parameters.

The methodology was applied to a well in Blocks 01&02 of the Cuu Long basin, where five major sand bodies were subdivided into 15 distinct sub-intervals subject to log response variations. Results reveal substantial intra-sand-body heterogeneity: Sands 1 - 4 consistently exhibit high risk with measured values below critical thresholds, while Sand 5 overall appears low-medium risk. A detailed analysis of Sand 5 identifies three distinct sub-intervals with dramatically different characteristics. Field validation confirmed prediction accuracy, with 600 psi depletion triggering sand production in the predicted intervals.

Based on these findings, active sand control measures are recommended for all high-risk intervals to ensure safe and sustainable production. The integrated multi-index approach provides enhanced reliability compared to single-criterion methods and can be readily applied to analogous geological settings with similar formation characteristics, offering a cost-effective alternative to extensive core testing programs.

**Key words:** Sand production prediction, geomechanics, weakly consolidated formations, Cuu Long basin, well completion.

## 1. Introduction

Sand production during oil and gas extraction represents one of the most significant technical challenges in the petroleum industry globally, including in Vietnam's offshore fields. This phenomenon occurs when formation particles are entrained and transported by flowing fluids during production, resulting in a cascade of detrimental consequences including (i) reduced production rates due

to plugged flow lines and equipment; (ii) erosion and damage to downhole and surface facilities; (iii) increased operational and maintenance costs; and (iv) potential well abandonment in severe cases. The industry estimates suggest that sand-related damage costs operators millions of dollars annually per affected well.

Over the past several decades, sand production prediction and control have attracted considerable attention from the international scientific community. Research efforts have focused on fundamental methodologies and models, as well as practical applications of wireline log analysis [1 - 10]. In Vietnam,



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sand production research initiatives began in the 2000s with significant contributions from Vietnamese researchers [11 - 14].

Accurate determination of formation mechanical properties and sand production potential is essential for deciding whether sand control equipment is necessary and, if so, which type is most appropriate. Sand production susceptibility depends on the complex interplay of formation mechanical properties, in-situ stress field, perforation orientation and design, and reservoir pressure depletion during production. Additionally, formation strength progressively degrades due to fluid-rock interaction effects during production. Without proper completion design in the initial well completion phase, operators may face significant remedial costs, production deferment, or, in extreme cases, total well loss.

Various authors have proposed sand production prediction models based on field observations, drilling data, and laboratory core testing [2, 3, 7, 10]. However, these approaches suffer from several practical limitations:

- High cost and long testing durations: Core acquisition and laboratory testing programs are expensive and time-consuming, particularly in offshore environments.

- Limited sample availability: Many fields have restricted core coverage with limited numbers and sizes of samples, which is insufficient for comprehensive model calibration and regional extrapolation.

- Sample quality concerns: Core handling and preservation practices, differences between reservoir and laboratory conditions, and equipment limitations can compromise test results.

- Coverage gaps: Core data rarely provides complete vertical coverage of production intervals.

In contrast, basic wireline log measurements are routinely acquired in virtually all wells, providing excellent vertical resolution and formation representativeness.

This study leverages standard wireline log data to derive geomechanical parameters, which are then used to apply five established prediction indices: (i) compressional sonic transit time (DTCO), (ii) sand production index (B), (iii) Schlumberger sand production ratio (SR), (iv) combined elastic modulus ( $E_c$ ), and (v) unconfined compressive strength (UCS). These methods have been successfully implemented in various global petroleum provinces by multiple researchers [1, 4, 9, 15].

According to established criteria, formations with high sand production potential requiring sand control from initial completion are characterized by the following threshold values of:  $BI < 20,000$  MPa,  $SR < 1.24 \times 10^8$  MPa<sup>2</sup>,  $E_c < 26,080$  MPa,  $UCS < 27.58$  MPa, and  $DTCO > \sim 95$   $\mu$ s/ft. This integrated approach offers an alternative perspective on sand production prediction and can enhance the reliability of predictive models and sand control strategies for the study area and analogous geological settings.

The study area is located within Blocks 01&02 of the Cuu Long basin on the southern Vietnamese continental shelf (Figure 1). The basin has undergone multiple tectonic phases including rifting, intense compression, and thermal subsidence, resulting in complex geology and lithology with diverse depositional facies and sedimentary environments. The primary producing intervals in this area are Miocene formations characterized by weakly consolidated, predominantly interbedded sand-shale sequences, making sand production a major operational concern.

The regional stratigraphic column (Figure 1) clearly displays the sedimentary succession of the Cuu Long basin, spanning from Pre-Tertiary basement to Pliocene - Quaternary deposits.

Basement and syn-rift sequence (Pre-Tertiary to Early Oligocene): The Pre-Tertiary basement comprises weathered and fractured granitoids and metamorphic rocks, which serve as the primary fractured basement reservoir in the basin.

The overlying Eocene Ca Coi and Tra Cu formations (Sequences F and E) consist of conglomerate, sandstone, shale, and thin coal/marl layers deposited in proluvial - alluvial to lacustrine - swamp environments during the initial rifting phase.

The Early Oligocene Tra Tan formation (Sequences C and D) is dominated by shale with andesite and basalt interbeds, indicating continued rifting with volcanic activity.

Transitional sequence (Late Oligocene to Early Miocene): The Bach Ho formation (Sequences B1.1 and B1.2) marks a transition from rifting to thermal subsidence, comprising interbedded sand, silt, shale, and localized basalt/tuff layers in swamp - alluvial - lacustrine to fluvial - marginal marine settings. This formation represents a major clastic reservoir interval where sand production is a significant concern due to poorly consolidated sandstones.

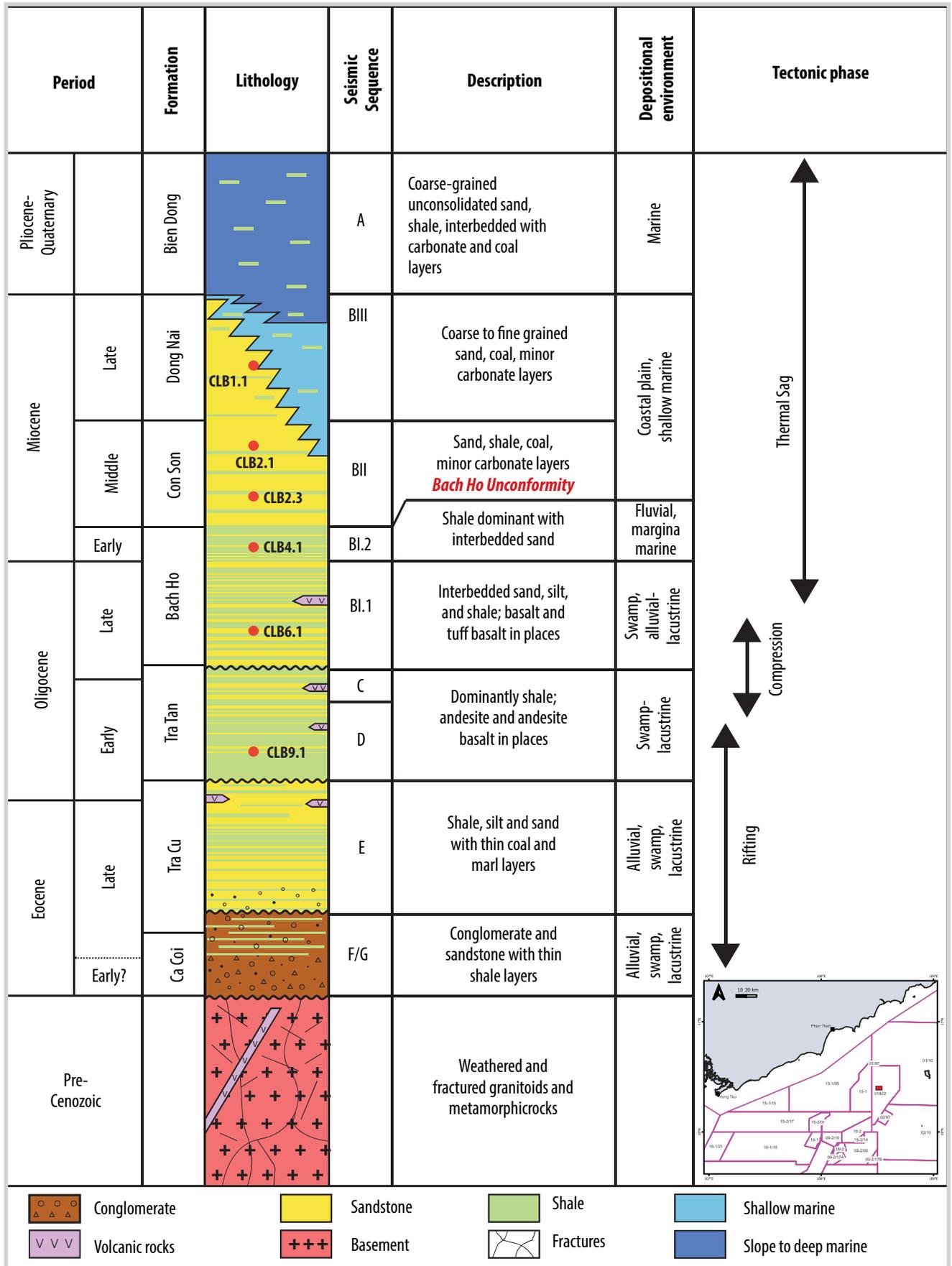


Figure 1. Study area and stratigraphic characteristics.

Post-rift thermal sag sequence (Middle Miocene to present): The Con Son, Dong Nai, and Bien Dong formations (Sequences B2, B3, and A) represent progressive marine transgression, evolving from fluvial - marginal marine to coastal - shallow marine and fully marine conditions. Lithologies grade upward from sand - shale - coal assemblages to coarse-grained unconsolidated sands with carbonate interbeds. These Miocene formations, particularly the Lower Miocene (Con Son) and Upper Miocene (Dong Nai) sequences, are the primary sand-producing intervals in the Cuu Long basin, characterized by weakly cemented, friable sandstones that are highly susceptible to sand production during hydrocarbon extraction.

## 2. Theoretical basis and methodology

### 2.1. Determination of geomechanical parameters

Accurate sand production prediction requires a comprehensive understanding of rock mechanical properties. Geomechanical parameters are derived from wireline log measurements, including gamma ray (GR), compressional sonic transit time (DTC,  $\mu\text{s}/\text{ft}$ ) or velocity ( $V_p$ ,  $\text{km}/\text{s}$ ), shear sonic transit time (DTS,  $\mu\text{s}/\text{ft}$ ) or velocity ( $V_s$ ,  $\text{km}/\text{s}$ ), and bulk density ( $\rho_b$ ,  $\text{kg}/\text{m}^3$ ). Key geomechanical parameters, including Poisson's ratio ( $\nu$ ), shear modulus ( $G$ , MPa), bulk modulus ( $K_b$ , MPa), Young's modulus ( $E$ , MPa), and unconfined compressive strength (UCS, MPa) are derived from Equations (1 - 6).

- Poisson's ratio ( $\nu$ )

Poisson's ratio represents the ratio of transverse (lateral) strain to axial strain under uniaxial stress, quantifying the deformation response of formations to in-situ stress. It is calculated from compressional ( $V_p$ ) and shear ( $V_s$ ) wave velocities:

$$\nu = \frac{(V_p^2 - 2V_s^2)/[2(V_p^2 - V_s^2)]}{(DTS^2 - 2DTC^2)/[2(DTS^2 - DTC^2)]} \quad (1)$$

- Shear modulus ( $G$ )

Shear modulus represents the ratio of shear stress to shear strain, quantifying resistance to shape deformation. It is derived from bulk density ( $\rho_b$ ) and shear wave velocity ( $V_s$ ):

$$G_{dyn} \text{ (MPa)} = \rho_b \times V_s^2 \quad (2)$$

- Bulk modulus ( $K_b$ )

Bulk modulus quantifies resistance to volumetric compression, representing the inverse of compressibility:

$$K_{b,dyn} \text{ (MPa)} = \rho_b \times (V_p^2 - 4/3 \times V_s^2) \quad (3)$$

- Young's modulus ( $E$ )

Young's modulus, or elastic modulus, represents the ratio of axial stress to axial strain, quantifying formation stiffness:

$$E \text{ (MPa)} = \rho_b V_s^2 \times (3V_p^2 - 4V_s^2)/(V_p^2 - V_s^2) = 9K_b G/[3(K_b + G)] \quad (4)$$

- Unconfined compressive strength (UCS)

UCS quantifies formation resistance to axial deformation under overburden pressure. For shale formations, the Horsrud [16] correlation is applied:

$$UCS \text{ (MPa)} = 0.77 \times V_p^{2.93} \quad (5)$$

For weakly consolidated sandstones, the McNally [17] relationship is employed:

$$UCS \text{ (MPa)} = 1200 \times \exp[-0.0367(304800/V_p)] \quad (6)$$

### 2.2. Sand production prediction methodologies

To assess sand production potential, the following five complementary criteria are applied:

- Compressional sonic transit time method

Formation consolidation strength is indicated by compressional wave velocity; lower velocities correlate with higher susceptibility to failure and sand production. Empirically, formations with compressional sonic transit times below 95  $\mu\text{s}/\text{ft}$  are generally stable. Conversely, higher transit times indicate elevated sand production risk requiring mitigation measures. The critical threshold varies among fields, but for weakly consolidated sandstones, sand production typically occurs when the DTCO exceeds 95  $\mu\text{s}/\text{ft}$  [4]. For this study, a slightly more optimistic threshold of 93  $\mu\text{s}/\text{ft}$  is adopted to optimize prediction criteria.

- Sand production index (BI) method

Petroleum engineers routinely employ wireline logs for assessing sand production due to difficulties in obtaining intact core samples from unconsolidated sands. Two principal log-based methods exist: the Schlumberger ratio (SR) and the sand production index (BI). Higher BI values indicate greater elastic modulus and superior rock strength. According to Dong et al. [4], formations with BI below 20,000 MPa exhibit high sand production potential and require control measures. The index is calculated as:

$$BI = E/[3(1 - 2\nu)] + (4/3) \times E/[2(1 + \nu)] \quad (7)$$

where: BI = sand production index (MPa); E = dynamic Young's modulus from logs (MPa);  $\nu$  = dynamic Poisson's ratio from logs

- Schlumberger sand production ratio (SR) method

For more precise strength and sand production assessment, Schlumberger's model defined the SR index based on bulk modulus ( $K_p$ ) and shear modulus (G) per Equation (8). Similar to BI, higher SR values indicate greater strength due to increased elastic, shear, and bulk moduli. Schlumberger established that SR values below  $1.24 \times 10^8$  MPa<sup>2</sup> indicate high sand production potential [4, 6, 9]:

$$SR = K \times G = [E/3(1-2\nu)] \times [E/2(1+\nu)]$$

- Combined elastic modulus ( $E_c$ ) method

This method utilizes sonic and density logs to calculate  $E_c$ . Formations become unstable and produce sand when  $E_c$  falls below 26,080 MPa, requiring sand control measures [4, 6, 9]:

$$E_c = (3.03 \times 10^8 \times \rho_b) / DTCO_2$$

where:  $E_c$  = combined modulus sand production index (MPa); DTCO = compressional sonic transit time ( $\mu$ s/ft);  $\rho_b$  = bulk density ( $g/cm^3$ )

- Rock strength (UCS) method

According to formation mechanical principles, weaker sands with lower UCS exhibit higher sand production potential and instability during drilling and production. In this study area, formations with UCS below 27.58 MPa are classified susceptible to sand production.

### 3. Results and discussion

#### 3.1. Lithology identification and geomechanical characterization

The study area was subdivided into sand and shale lithologies based on gamma ray log response. Specifically, Sand bodies 1, 2, 3, and 4 exhibit gamma ray values below

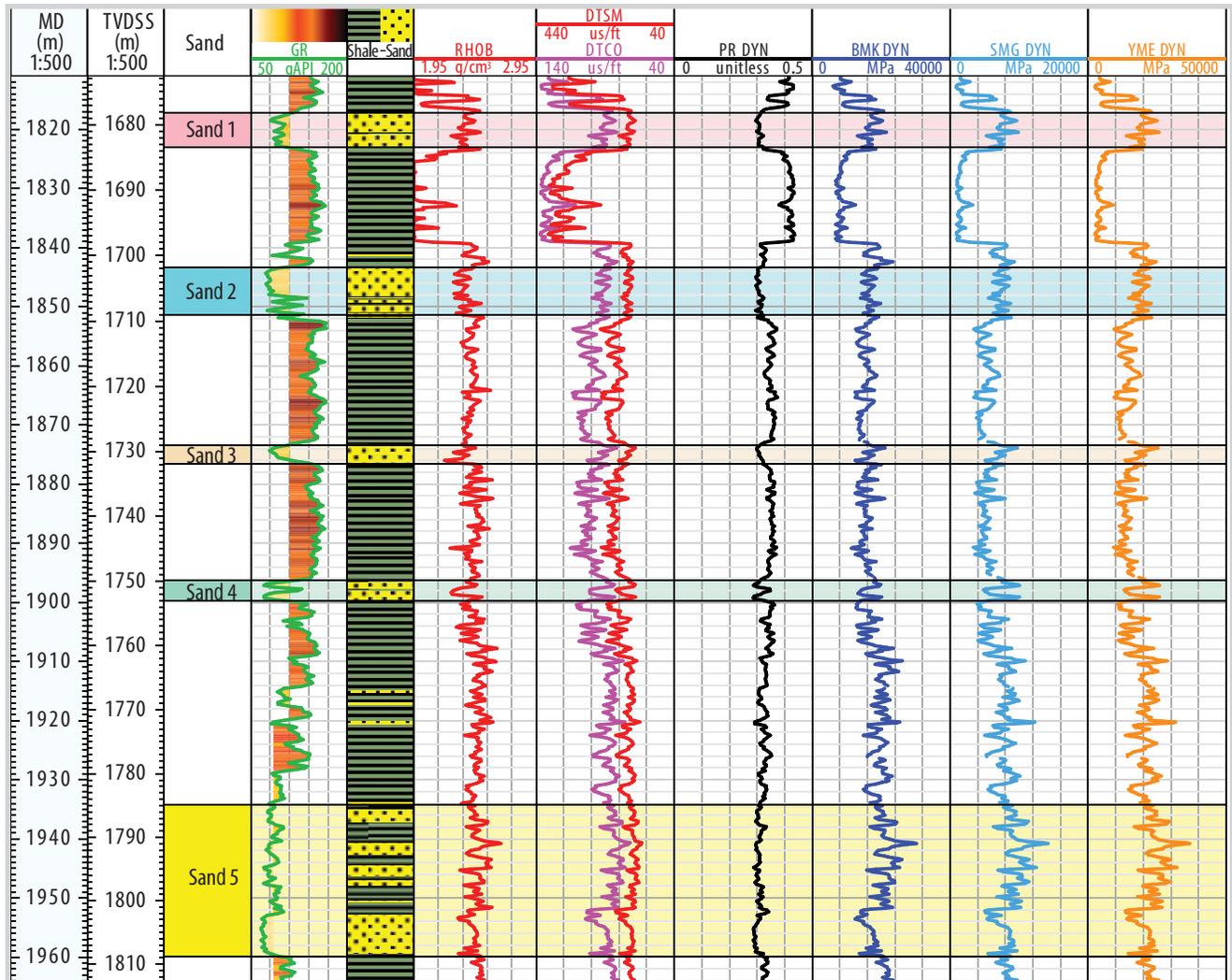


Figure 2. Lithology and data input for sanding risk analysis.

**Table 1.** Geomechanical parameters for individual sub-intervals showing intra-sand-body variability

Sand intervals	Sub-interval	Depth (m)	Poisson ratio	Bulk modulus (MPa)	Shear modulus (MPa)	Young modulus (MPa)	UCS (MPa)	DTCO (µs/ft)
Sand 1	Sand 1a	1,817 - 1,821	0.310	16,800	7,350	18,200	25.8	92.5
	Sand 1b	1,821 - 1,823	0.307	17,200	7,650	19,400	27.9	89.8
Sand 2	Sand 2a	1,843 - 1,845	0.309	16,450	7,280	19,050	26.9	91.2
	Sand 2b	1,845 - 1,847	0.312	16,100	7,100	17,800	25.1	93.8
	Sand 2c	1,847 - 1,849	0.306	16,750	7,380	19,350	27.4	90.5
	Sand 2d	1,849 - 1,851	0.305	16,900	7,500	19,900	28.1	89.2
Sand 3	Sand 3a	1,873 - 1,875	0.311	16,500	7,180	18,750	26.2	92.1
	Sand 3b	1,875 - 1,876	0.310	16,600	7,240	19,020	26.6	91.6
Sand 4	Sand 4a	1,896 - 1,898	0.313	16,450	7,150	18,480	25.5	93.2
	Sand 4b	1,898 - 1,899	0.309	16,750	7,400	19,550	27.6	91.0
Sand 5	Sand 5a	1,934 - 1,953	0.304	20,100	9,050	24,500	33.8	83.5
	Sand 5b	1,953 - 1,955	0.308	16,250	7,100	19,100	26.5	95.2
	Sand 5c	1,955 - 1,959	0.307	19,500	8,650	22,800	31.2	87.8

110 API, while Sand 5 shows values below 85 API (Figure 2). Individual sand body thicknesses range from 3.2 to 25.73 m as detailed in Tables 1 and 2. According to field reports [18], these productive intervals began experience sand production after approximately 600 psi of reservoir pressure depletion.

Figure 2 and Table 1 present calculated geomechanical parameters and rock strength derived from wireline log data. Average values for Sands 1 - 5 include Young's modulus (YME\_DYN) of 18,888 - 23,204 MPa, shear modulus (SMG\_DYN) of 7,212 - 8,894 MPa, bulk modulus (BMK\_DYN) of 16,536 - 19,851 MPa, and Poisson's ratio (PR\_DYN) of 0.305 - 0.311. Minimum YME\_DYN and SMG\_DYN occur in Sand 3, while minimum BMK\_DYN and PR\_DYN occur in Sand 2 and Sand 5, respectively.

Rock strength (UCS) ranges from 26.08 to 32.69 MPa across all intervals. The minimum UCS of 26.08 MPa in Sand 4 indicates the weakest consolidation, which, when combined with its limited thickness (3.42 m), suggests a significant influence from bounding shale intervals, resulting in elevated sand production potential. Conversely, Sand 5 exhibits maximum UCS (32.69 MPa) along with the highest elastic, shear, and bulk moduli. Additionally, greater burial depth subjects Sand 5 to increased overburden stress, further enhancing consolidation. Therefore, Sand 5 demonstrates superior consolidation and the lowest sand production risk among all intervals.

### 3.2. Sand production risk assessment

Geomechanical parameters were utilized to calculate sand production indices according to the methodologies described above. Results are presented in Table 2 and Figure 3.

#### - Compressional sonic transit time analysis

Formations with high sand production potential exhibit DTCO values exceeding 93 µs/ft, representing a slight optimization from the 95 µs/ft threshold proposed by Dong et al. [4]. Analysis of Figure 3 and Table 2 reveals DTCO values ranging from 85 to 135 µs/ft, with interval averages of 85.75 to 92.61 µs/ft. Sands 1 - 4 show average values of 90.59 - 92.61 µs/ft, all exceed the 90 µs/ft threshold, while Sand 5 (85.75 µs/ft) falls below. These results indicate that Sands 1 - 4 exhibit higher sand production potential than Sand 5 by this criterion, although isolated intervals within Sand 5 exceed the threshold (shown in red, Figure 3).

#### - Sand production index (BI) analysis

Increasing BI values indicate greater elastic modulus and enhanced rock stability. Formations with BI below 20,000 MPa exhibit high sand production potential [4]. For the study area, average BI values for Sands 1 - 5 are 20,427.79, 19,906.36, 19,900.20, 19,934.94, and 23,372.15 MPa, respectively (Table 2 and Track 7, Figure 3). Only Sand 1 and Sand 5 exceed the threshold, indicating that Sand 5 exhibits the lowest sand production risk by this criterion.

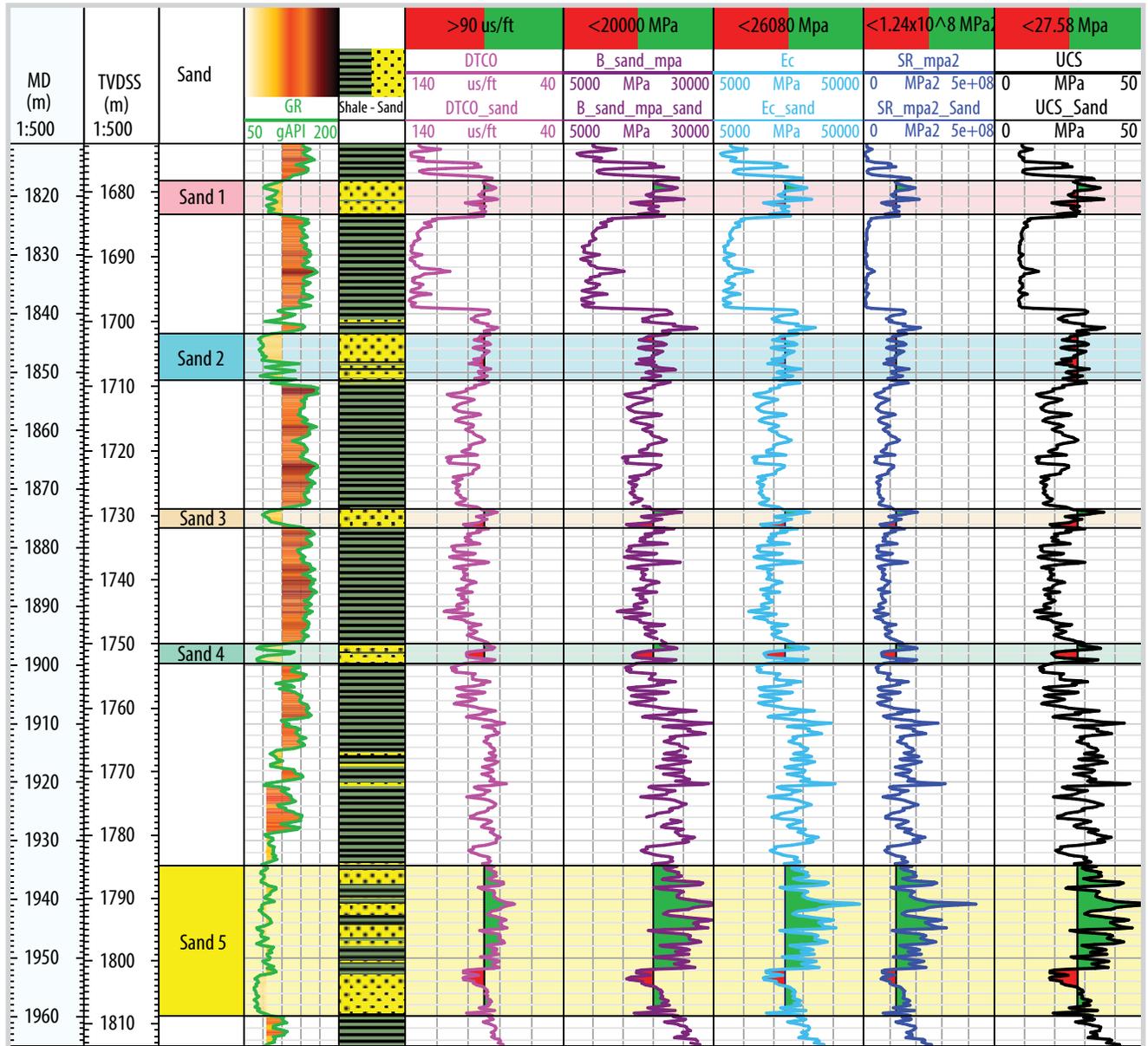


Figure 3. Sand production indices.

- Schlumberger sand production ratio (SR) analysis

Track 9 in Figure 3 highlights intervals where SR <  $1.24 \times 10^8$  MPa<sup>2</sup> (red shading), indicating elevated sand production potential that requires control measures [6, 9]. Table 2 shows the average SR values for Sands 1 - 5, ranging from 1.22 to  $1.82 \times 10^8$  MPa<sup>2</sup>. Only Sand 5 exceeds the critical threshold, confirming lower sand production susceptibility compared to other intervals.

- Combined elastic modulus (E<sub>c</sub>) analysis

According to multiple researchers [1, 4, 6, 9], formations with E<sub>c</sub> below 26,080 MPa require sand control. Track 8 in Figure 3 displays intervals below this threshold in red, indicating higher sand production potential.

Average E<sub>c</sub> values range from 26,009 to 31,516 MPa across all intervals. Only Sand 3 falls below the critical value.

- Rock strength (UCS) analysis

Table 2 demonstrates that Sand 5 exhibits the highest UCS (32.69 MPa), exceeding the 27.58 MPa threshold, while all other intervals fall below this value. These results confirm that active sand control measures are required throughout the productive life of well for Sands 1 - 4.

Table 2 identifies specific depth intervals within each sand body that exhibit the highest sand production potential based on the integrated multi-index assessment. These intervals should be avoided during perforation planning if sand control equipment is not installed or given priority for active sand control implementation.

Table 2. High sand production risk intervals within sand bodies

No.	Sub-Interval	Depth (m)	Thick (m)	DTCO (μs/ft)	BI (MPa)	SR (×10 <sup>8</sup> MPa <sup>2</sup> )	Ec (MPa)	UCS (MPa)	Risk
	Threshold →			> 93	< 20,000	< 1.24	< 26,080	< 27.58	
1	Sand 1a	1,817 - 1,821	3.75	96.8	17,200	1.08	22,500	25.2	High
2	Sand 1b	1,821 - 1,823	2.06	94.5	18,800	1.15	24,200	26.8	High
3	Sand 2a	1,843 - 1,845	2.09	95.2	18,200	1.12	23,800	26.2	High
4	Sand 2b	1,845 - 1,847	2.00	97.5	16,800	1.05	21,900	24.8	High
5	Sand 2c	1,847 - 1,849	2.40	94.8	18,500	1.18	24,500	27.1	High
6	Sand 2d	1,849 - 1,851	1.50	93.5	19,200	1.20	25,200	28.2	High
7	Sand 3a	1,873 - 1,875	1.61	98.2	16,200	1.02	21,200	24.2	High
8	Sand 3b	1,875 - 1,876	1.62	97.8	16,500	1.04	21,500	24.5	High
9	Sand 4a	1,896 - 1,898	1.69	96.5	17,500	1.09	22,800	25.5	High
10	Sand 4b	1,898 - 1,899	1.73	94.2	18,900	1.16	24,800	27.2	High
11	Sand 5a	1,934 - 1,953	18.78	83.5	24,200	1.45	30,500	33.8	Low
12	Sand 5b	1,953 - 1,955	2.00	95.2	17,800	1.11	19,100	26.5	High
13	Sand 5c	1,955 - 1,959	4.95	93.8	21,500	1.18	22,800	31.2	Medium

**4. Conclusions and recommendations**

This study demonstrates that standard wireline log measurements can be used to derive key geomechanical parameters (Poisson's ratio, Young's modulus, bulk modulus, shear modulus) and rock strength (UCS). Five complementary prediction methodologies were applied: compressional sonic transit time, sand production index (BI), Schlumberger ratio (SR), combined elastic modulus (E<sub>c</sub>), and UCS.

Analysis of five sand bodies in the study well reveals that Sands 1 - 4 exhibit high sand production potential, indicating the need for proactive completion design and sand control implementation prior to initial production. In contrast, Sand 5 shows the lowest sand production susceptibility. However, even in the absence of sand control measures, perforation of the high-risk depth intervals identified in Table 3 should be avoided to minimize sand production issues.

The integrated multi-index approach presented in this study offers several significant advantages:

- Cost-effectiveness: Reliance on routinely acquired wireline log data reduces dependence on expensive core acquisition and laboratory testing, shortening project timelines and lowering costs and.
- Enhanced coverage: Wireline logs provide continuous vertical coverage of production intervals, enabling comprehensive reservoir characterization.
- Improved reliability: The multi-index approach reduces uncertainty by achieving consensus among

multiple independent prediction criteria, increasing reliability against single-method assessments.

- Regional applicability: The methodology can be readily extended to adjacent areas and analogous geological settings with similar formation characteristics, facilitating rapid field development planning.

While this study confirms the effectiveness of log-based sand production prediction, several areas warrant further investigation:

- Validation against production history: Systematic comparison of predictions with actual sand production rates and volumes from multiple wells would enable statistical validation and threshold calibration for the Cuu Long basin.
- Integration with core data: Where available, core-derived mechanical properties should be correlated with log-calculated values to assess accuracy and potentially develop basin-specific empirical corrections.
- Time-lapse assessment: Monitoring sand production evolution with reservoir depletion through periodic logging or downhole monitoring could reveal threshold changes and enable dynamic risk reassessment.
- Machine learning applications: With sufficient data volume, supervised learning algorithms could potentially optimize index weighting or discover additional predictive log signatures.

This integrated geomechanical approach provides a robust and cost-effective framework for sand production risk assessment in weakly consolidated formations. By

leveraging standard wireline log data through multiple complementary prediction indices, operators can make informed decisions regarding completion design, sand control strategy, and perforation planning, ultimately enhancing production efficiency and reducing operational risks in challenging reservoirs such as those encountered in the Cuu Long basin.

## References

- [1] T.J. Ajayi, O.Y. Adeogun, and Omeru, "Predicting sanding potential using empirical method in "Ebendo" field, Niger Delta, Nigeria", *Journal of Applied Sciences and Environmental Management*, Volume 26, Issue 9, pp. 1557 - 1564, 2022.
- [2] Sadegh Asadi, Khalil Rahman, Hoanh V. Pham, Thao Le Minh, and Andy Butt, "Sand production assessment considering the reservoir geomechanics and water breakthrough", *The APPEA Journal*, Volume 55, Issue 1, p. 215 - 224, 2015. DOI: 10.1071/aj14016.
- [3] I.D.R. Bradford, J. Fuller, P.J. Thompson, and T.R. Walsgrove, "Benefits of assessing the solids production risk in a North Sea reservoir using elastoplastic modelling", *SPE/ISRM Rock Mechanics in Petroleum Engineering, Trondheim, Norway, 8 - 10 July 1998*. DOI: 10.2118/47360-MS.
- [4] Ma Dong, Bian Long, Li Lun, and Hu Juncheng, "Application of logging data in predicting sand production in oilfield", *Electronic Journal of Geotechnical Engineering*, Volume 18, pp. 6173 - 6180, 2013.
- [5] Ehsan Khomehchi and Ebrahim Reisi, "Sand production prediction using ratio of shear modulus to bulk compressibility (case study)", *Egyptian Journal of Petroleum*, Volume 24, Issue 2, pp. 113 - 118, 2015. DOI: 10.1016/j.ejpe.2015.05.002.
- [6] Osaki Lawson-Jack, Etim D. Uko, Iyeneomie Tamunobereton-Ari, and Matthew A. Alabraba, "Geomechanical characterization of a reservoir in part of Niger Delta, Nigeria", *Asian Journal of Applied Sciences and Technology*, Volume 3, Issue 1, pp. 10 - 30, 2019.
- [7] Khalil Rahman, Abbas Khaksar, and Toby Kayes, "Minimizing sanding risk by optimizing well and perforation trajectory using an integrated geomechanical and passive sand-control approach", *SPE Annual Technical Conference and Exhibition, Denver, Colorado, USA, 21 - 24 September 2008*. DOI: 10.2118/116633-MS.
- [8] Surej Kumar Subbiah, Lex de Groot, and Hilbrand Graven, "An innovative approach for sand management with downhole validation", *SPE International Symposium and Exhibition on Formation Damage Control, Lafayette, Louisiana, USA, 26 - 28 February 2014*. DOI: 10.2118/168178-MS.
- [9] Kingsley Maraizu Ogbuagu, Chukwuemeka Ngozi Ehirim, and Tamunonengiyeofori Dagogo, "Evaluation of formation susceptibility and sand production potential in an offshore field, Niger Delta basin, Nigeria", *Energy Geoscience*, Volume 5, Issue 1, 2024. DOI: 10.1016/j.engeos.2023.100213.
- [10] S.M. Willson, Z.A. Moschovidis, J.R. Cameron, and I.D. Palmer, "New model for predicting the rate of sand production", *SPE/ISRM Rock Mechanics Conference, Irving, Texas, 20 - 23 October 2002*. DOI: 10.2118/78168-MS.
- [11] Hoàng Thanh Tùng, Lê Thị Hoàng Thi, Trương Hoài Nam, Lê Vũ Quân, và Tạ Văn Cường, "Ứng dụng mô hình giải tích để dự báo khả năng sinh cát của các vỉa khí tầng miocene mỏ Hải Thạch, bể Nam Côn Sơn", *Tạp chí Dầu khí*, Số 12, trang 16 - 26, 2016.
- [12] Tạ Quốc Dũng, Lê Thế Hà, và Nguyễn Tiến Đạt, "Ứng dụng phương pháp địa thống kê trong dự báo các thông số địa cơ học và ứng dụng mô hình SANDPIT3D trong dự báo sinh cát cho giếng khai thác ở bể Nam Côn Sơn", *Tạp chí Dầu khí*, Số 4, trang 39 - 50, 2019.
- [13] Tạ Quốc Dũng, and Hoàng Thanh Tùng, "The model to predict sand production for production wells in the Cuu Long basin", *Journal of Science and Technology Development*, Volume 17, Issue 3, pp. 172 - 178, 2014. DOI: 10.32508/stdj.v17i3.1493.
- [14] Tạ Quốc Dũng, và Hoàng Trọng Quang, *Nghiên cứu điều kiện sinh cát và thiết lập chương trình mô phỏng sinh cát trong các giếng khoan khai thác dầu tầng Miocene thềm lục địa Việt Nam*. Trung tâm Phát triển Khoa học Công nghệ trẻ, 2003.
- [15] Per Horsrud, "Estimating mechanical properties of shale from empirical correlations", *SPE Drilling and Completion*, Volume 16, Issue 2, pp. 68 - 73, 2001. DOI: 10.2118/56017-PA.
- [16] G.H. McNally, "Estimation of coal measures rock strength using sonic and neutron logs", *Geoexploration*, Volume 24, Issue 4 - 5, pp. 381 - 395, 1987. DOI: 10.1016/0016-7142(87)90008-1.
- [17] Petronas, *HIIP and reserves assessment report*, 2013.