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Prediction of Sanding Likelihood Intervals Using Different Approaches

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Abstract

Sand production is undesirable matters, occurring in wells that are producing from sand reservoirs. It causes many problems such as erosion and grains accumulation in downhole and surface equipment's, and formation subsidence. Important stage in sanding problem solution is a prediction of likelihood sand production intervals. In present paper, a vertical well X1 that is producing from Asmari reservoir in Y field at southern Iraq was selected for study. Asmari reservoir was classified to six units: A, B1, B2, B3, B4, and C. B zones consisted from sandstone with others rock types. Eight approaches were used for prediction sanding onset intervals by dealing with X1 well as open hole completion. Utilized eight prediction methods are compressional sonic wave (CSW), unconfined compressive strength (UCS), total porosity (PHIT), shear modulus to bulk compressibility (G/Cb), B-Index, Schlumberger index (S- Index), combined index (Ec-Index) and critical drawdown pressure (CDDP). All these methods performed based on 2462 measured points of CSW, sonic shear wave log (SSW), and density log (DL). Sand production likelihood intervals was selected by determination of cutoff values of adopted methods. Sand is possible to occur if interval has values lower than cutoff values of G/Cb, UCS, B-Index, S-Index, Ec, and CDDP and greater than cutoff values of CSW, and PHIT. Obtained cutoff values of eight approaches were 800 x 109 psi2, 36 Mpa, 0.2, 80 us/ft, 10000 Mpa, 108 Mpa, and 2700 Mpa, of G/Cb, UCS, PHIT, CSW, B-Index, S-Index, and Ec respectively. As well as sand production is possible to occur of bottomhole flowing pressure lower than calculated CDDP. Some Intervals had high CDDP that referred to abnormal pressure zones consisted from shale. Determination of sand onset intervals is a key for selecting best methods for controlling.

Keywords: CDDP, Compressional sonic, Schlumberger index, Combined index, B index, Shear modulus to bulk compressibility ratio, Total porosity, Unconfined compressive strength.

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1. Introduction

Sandstones originated as a result of a complicated geological process that consists of two stages: deposition and decomposition. Combining individual grains together to create a whole mass is called deposition. Decomposition is the process through which newly deposited material is transformed into rock as a result of chemical reactions (chemical breakdown or physical decomposition of minerals) [1]. Sand production is sand grains flowing alongside produced hydrocarbons and water at certain conditions [2]. According to [3], over 60% of oil and gas wells in the Middle East are produced from sandstone formations, but this ratio rises to 70% when including all global fields [4, 5, 6, 7, 8].

Optimal sand management requires a complete understanding of the causing parameters of sand problems, so different validated methods and tools can be developed for predicting sand onset production and controlling it [9]. Changes in formation consolidation degree, water breakthrough, reservoir pressure depletion, changes in production rate, difference in viscosity and velocity of produced fluid, tectonic stress, heterogeneity of formation, and formation temperature effects all contribute to sand production [10, 11, 12, 13, 14, 15].

Based on field observations, sand production is classified into three types: (1) transient sanding due to acidizing, clean up after perforation, and water breakthrough. It declines with time under the same production conditions, (2) continues sand production; sand accumulates inside the wellbore and increases the hold-up depth. Depending on the sand domination and the lifting capacity of the fluid flow, the producing interval may eventually be blocked. Sometimes, it is continuing in acceptable amounts depending upon operational limitations regarding erosion, capacity of separators, sand depositions, artificial lift, well location, etc., and (3) Catastrophic high rate of sand influx due to sudden shut in/open well, which is divided into two failure scenarios. shut down operations, as well as other massive sand influxes that fill the well's bottom [3, 16].

Sand production can be predicted by using many empirical methods based on well log data and rock mechanical properties [17, 18, 19], in addition to spectral sonic log tools that are used in conjunction with production log tools [20]. Based on the sand production prediction estimates of selected wells, downhole and surface sand control tools for future wells will be selected and designed [21].

The aim of the present study is to predict sanding onset intervals of X1 well that is producing from the Asmari reservoir in Y field by adopting eight methods of compressional sonic wave

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(*CSW*), unconfined compressive strength (*UCS*), total porosity (*PHIT*), shear modulus to bulk compressibility (G/C_b), B-Index, Schlumberger index (*S- Index*), combined index (*Ec-Index*) and critical drawdown pressure (*CDDP*) for dealing with X1 well as open hole completion.

1.1. Geological Setting

Y oil field is located in the south of Iraq specifically in Missan governorate, away 50 km to north–east of Ammara city and 175 km north of Basrah city as showed in Figure (1), The field is extending along the Iraq - Iran borders, from the east, it is a few kilometers away from the Buzrgan oil field. Y oil field have two domes with north-west, south-east anticline in north and south respectively. Some of field part and most of north dome stretch in Iran. Field length about 23 km and width about 7 km. According to the last available information about the field in 2021, the number of production wells in south and north domes of Y oil field reach to sixty-nine between vertical and directional well with one water injection well. The production of wells is distributed between Asmari and Mishrif formations only or from both at same time [22]. Asmari is a target formation in present study.

Earlier studies about target formation such as [23] classified it to main four zones A refers to Jeribe-Euphrates B correspond to Upper Kirkuk, and C and D belong to Middle-Lower Kirkuk reservoirs. But in recent years, new wells have been drilled, and production has increased so water level is rising and both C and D units merged as a one water zone with title C. Modern studies divided Asmari formation as three main zones represented by A, B and C and the first two are the main reservoirs, The A zone of Asmari is mostly composed of dolomite. Dolomite is intercalated with sandstone, limestone, and thin shale in B zone. The C zone is mostly sandstone, with a few dolomites, mudstone, and limestone intercalated.

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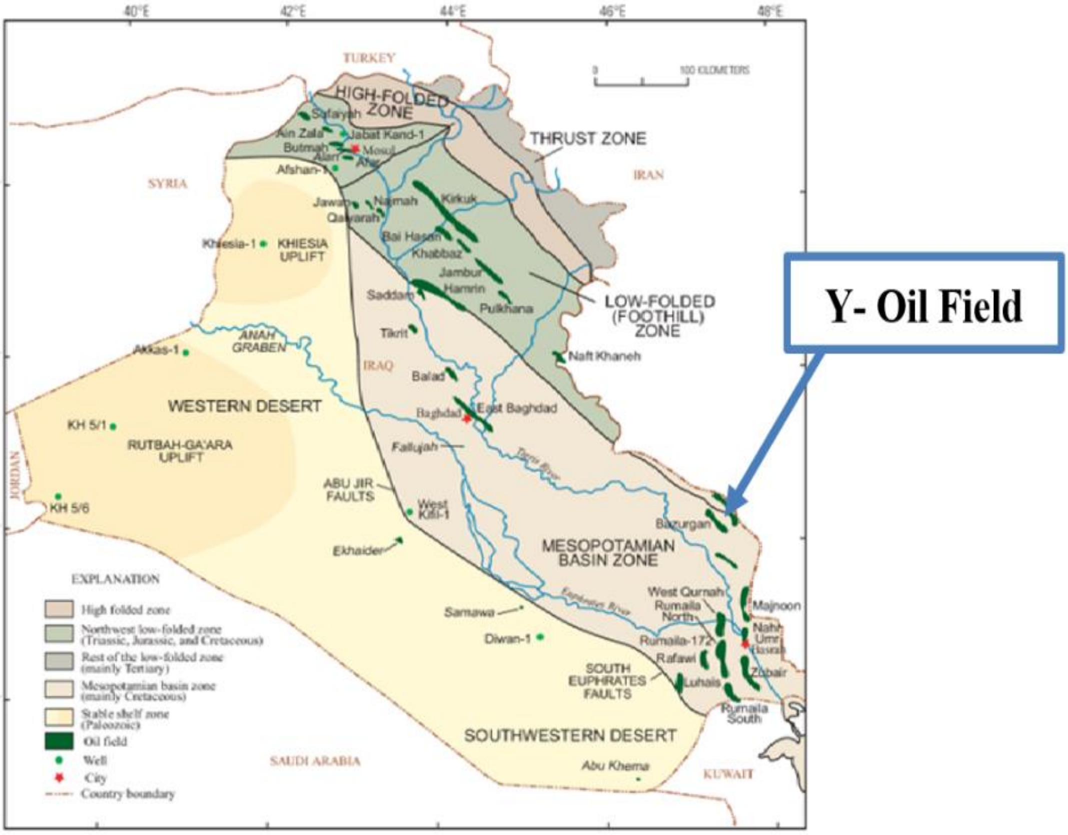

Fig. (1): Y oil field in Iraq map [24, 25, 26].

2. Materials and Methods

One vertical well X1 that producing from Asmari formation at Y oil field is selected for this study. 2462 measured points of *CSW*, *SSW*, and *DL* logs are used as a basic for sand production onset intervals by following eight methods:

2.1. Shear Modulus and Rock Compressibility Ratio (G/C_b) Method

According to [25], *G* is a significant elastic parameter for detecting sanding problems. Their principles are employed for sand production prediction by determining the critical limit of principle rock strength that concludes from *G* and rock compressibility (C_b) that determined based on well log measurements [17]. Applied cases on North Sea fields revealed that a threshold ratio of (G/C_b) is ($0.8 \ x\ 10^{12}$ psi^2), implying that sand will be produced below this number. the following equations provided by [6, 26, 27] are used for G/C_b as follows:

$$\frac{G}{C_b} = \frac{E^2}{6\,(1+PR).(1-2PR)} \tag{1}$$

Where *E* is a Youngs modulus (psi), and *PR* is a Poisson ratio.

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2.2. Unconfined Compressive Strength (*UCS*) Method

The continuous profiles of mechanical rock properties were described and used in applications for drilling, production, and improved reservoir modeling by [28] indicated that sanding is likely to happen if *UCS* is less than 7250 psi (50 MPa). *UCS* is calculated by following Brie shear modulus formula:

$$UCS = 5{,}6x10^{-6}.G_{Ref-sand}(\frac{G_{dyn}}{G_{Ref-sand}}) \tag{2}$$

Where $G_{Ref\text{-}Sand}$ is a reference shear modulus for sandstone has default value equal to 40000 Mpa and G_{dyn} is a dynamic shear modulus (Mpa).

2.3. Total Porosity (*PHIT*) Method

Another empirical method for indicating the onset of a sanding problem was adopted in different literature, sand production functionality in sandstone formations with *PHIT* greater than 30%, and slightly sand production capability in the range 20% - 30%, so these formations with *PHIT* greater than 30% without sand control measurements and tools, a sand producing will be very serious in area [18]. Porosity is calculated by using density – neutron equation:

$$PHIT = \sqrt{\frac{PHIT_D{}^2 + PHIT_N{}^2}{2}} \tag{3}$$

Where $PHIT_D$ and $PHIT_N$ are determined total porosity from density and neutron logs.

2.4. Compressional Sonic Wave (*CSW*) Method

CSW in (us/ft) may be used as an indicator for predicting sanding onset; if *CSW* is greater than 89.9, sand production will occur; otherwise, production will be free sand [18, 19], but another study of [29] showed some slightly different in threshold value as sand still stable without production if *CSW* is less than or equal to 95, while sand may be produced if the *CSW* is between 95 and 105, sand is produced if the *CSW* is more than 105. These varied values are determined by the variation in formations nature.

2.5. $B_{\text{-index}}$ Method

Some loose sand formations are difficult to obtain core samples from, so well log measurements can be used to determine B_{index} in (psi unit) as a sand production index; higher B_{index} value indicate a high strength formation, and according to literature, if B_{index} is less than 2.9 x 10^6 psi (20000 Mpa), sanding problems will occur, indicating that B_{index} is lower and sand risk

Open Access
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is higher. B_{index} determined using the following formulas [19, 29]:

$$B_{index} = \frac{E}{3\,(1-2\,PR)} + \frac{4}{3} . \frac{E}{2\,(1+PR)} \qquad (4)$$

2.6. Schlumberger Index (S_{-index}) Method

After conducting several tests on oil wells in Mexico Gulf, Schlumberger proposed the following approach. It is proposed that no sand is formed when S is greater than 5.51 x 10^9 psi (3.799 x 10^7 Mpa) and that sand may be produced when S is less than 4.79 x 10^9 psi (3.3 x 10^7 Mpa). S_{index} is calculated using the following equation [18]:

$$S_{index} = \frac{(9.94\ x\ 10^8)^2 (1-2PR)(1+PR).DL}{6\,(1-PR)^2\ CSW^4} \qquad (5)$$

Where DL is a density log (gm/cc), and CSW is a compressional sonic log (us/ft).

2.7. Combined Modulus ($E_{C\text{-index}}$) Method

Combined modulus is another empirical sand predicting method that uses log measurements to calculate $E_{C\text{-index}}$, with platu value indicating no sand if $E_{C\text{-index}}$ is greater than or equal to 2.88 x 10^6 psi (1986 Mpa), light sand produced if it is between 2.16 x 10^6 and 2.88 x 10^6 psi (1489-1986 Mpa), and high sand production if it is less than 2.16 x 10^6 psi (1489 Mpa). $E_{C\text{-index}}$ is computed using the following equation [18]:

$$E_{C\text{-}index} = \frac{9.49\ x\ 10^8 .DL}{CSW^2} \qquad (6)$$

2.8. Critical Drawdown Pressure (*CDDP*) Method

CDDP as defined previously is a maximum difference between reservoir pressure and bottom hole flowing pressure will be produced below its sand. A method for calculating *CDDP* was proposed by [30]. It is based on a fundamental appearance strength demand imposed to a construction component near the wall of a cylindrical hole, with linear-elastic behavior assumed. They are obtained the following equation in term of *CDDP* in psi:

$$CDDP = \frac{1}{2-M} [2P_p - (3S_{Hmax} - S_{hmin} - U) \qquad (7)$$

Where M is a poro-elastic constant and representing by following formula:

$$M = \frac{\alpha\,(1-2PR)}{1-PR} \qquad (8)$$

From the thick wall cylinder model (*TWC* in psi), the formation strength (*U* in psi) equal to:

Open Access
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$$U = 2.5\,TWC \quad (9)$$

In open hole, *TWC* is calculating based on *UCS* as follow:

$$TWC = 9.1\,UCS^{0.61} \quad (10)$$

3. Results and Discussion

Vertical X1 well is dealing as open hole completion. Obtained results from all mentioned eight methods are approximately identical as shown in Figure (2) and Figure (3). There are many parameters that affect sand production, such as cohesion degree between rock particles, reservoir pressure depletion due to high production, produced fluid type and properties, tectonic stresses, and formation heterogeneity. Some of these causing parameters are considered directly or indirectly in the eight methods for sanding onset prediction. Generally, declining values of G/C_b, *UCS*, $B_{\text{-index}}$, $S_{\text{-index}}$, and $E_{C\text{-index}}$ curves lower than critical values of these methods and exceeding values of *PHIT*, and *CSW* curves than critical values of these methods indicating to the weak formation that can be breaking down during drilling or production. To show the confusing about weak formation type, lithology is determined as depicted in first tracks of Figure (2) and Figure (3), so, determination of lithology is showing the difference in two weak formations as sand or shale that declining or exceeding than critical values with respect to adopted mentioned methods. *CDDP* is calculated for four difference depletion rates of 0%, 15%, 25% and 35%. *CDDP* method had a one difference than seven methods where intervals that have *CDDP* lower than normal trend is referring to sand onset intervals and that will be providing match with other seven methods, while *CDDP* values that greater than normal is referring to up normal pressure shale intervals. Critical values of eight methods except *CDDP* method is listing in Table (1). The differences in some critical limits in Table (1) from those indicated in the literature of methods at materials and methods part are to be expected because each method was developed based on a specific reservoir data, resulting in this dissimilarity based on differences in reservoir properties, amount and types of fluid content and lithology. Most of the depths that correspond to the green color after the left of cutoff baseline are subject to the production of sand, and we see that there is a great match between all the methods, as well as *CDDP* belong to these intervals is low and that another indication for sanding problem in these intervals.

Open Access
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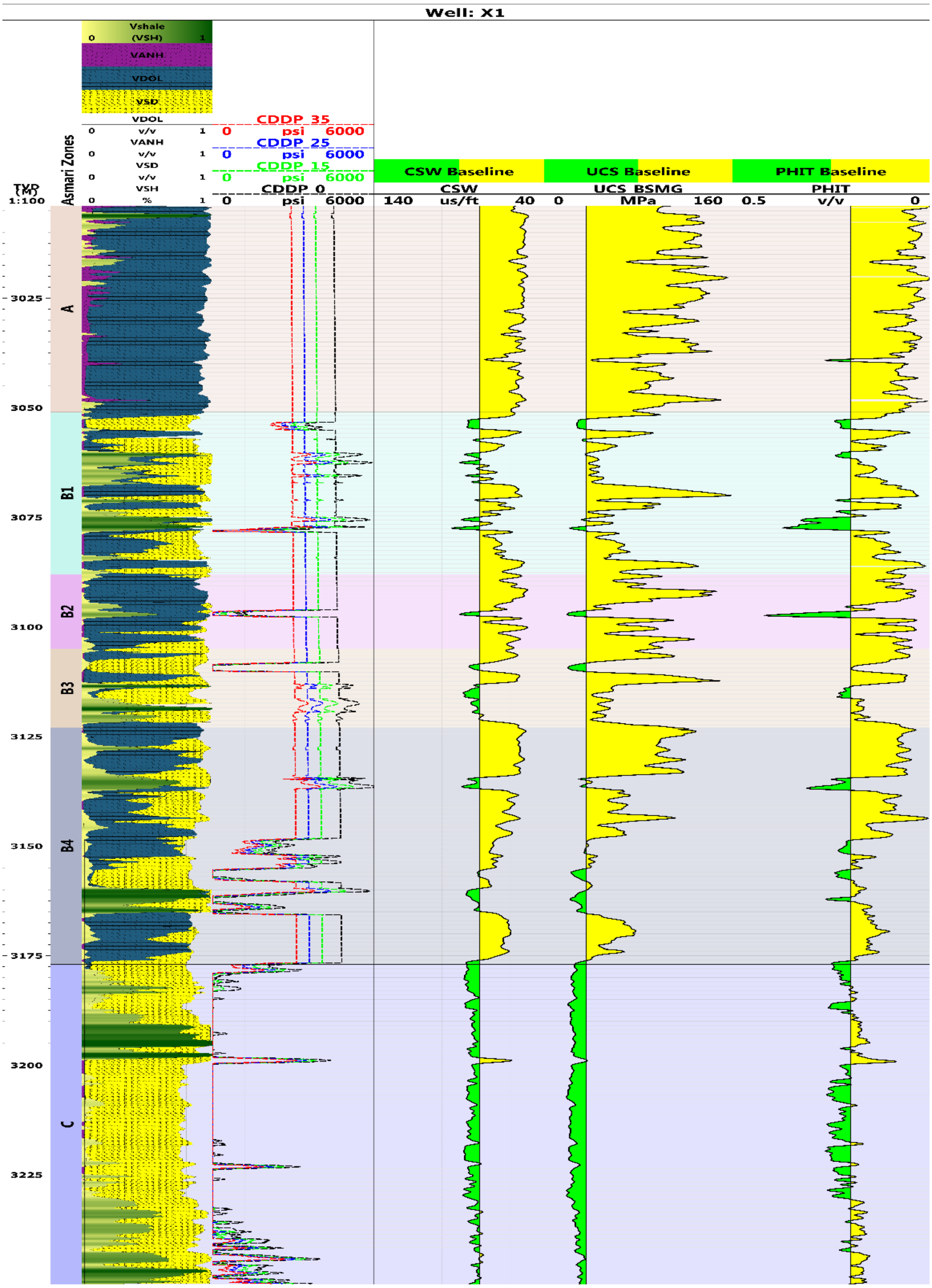

Fig. (2): Sanding intervals prediction by *CDDP*, *CSW*, *UCS*, and *PHIT* of X1 well.

Open Access
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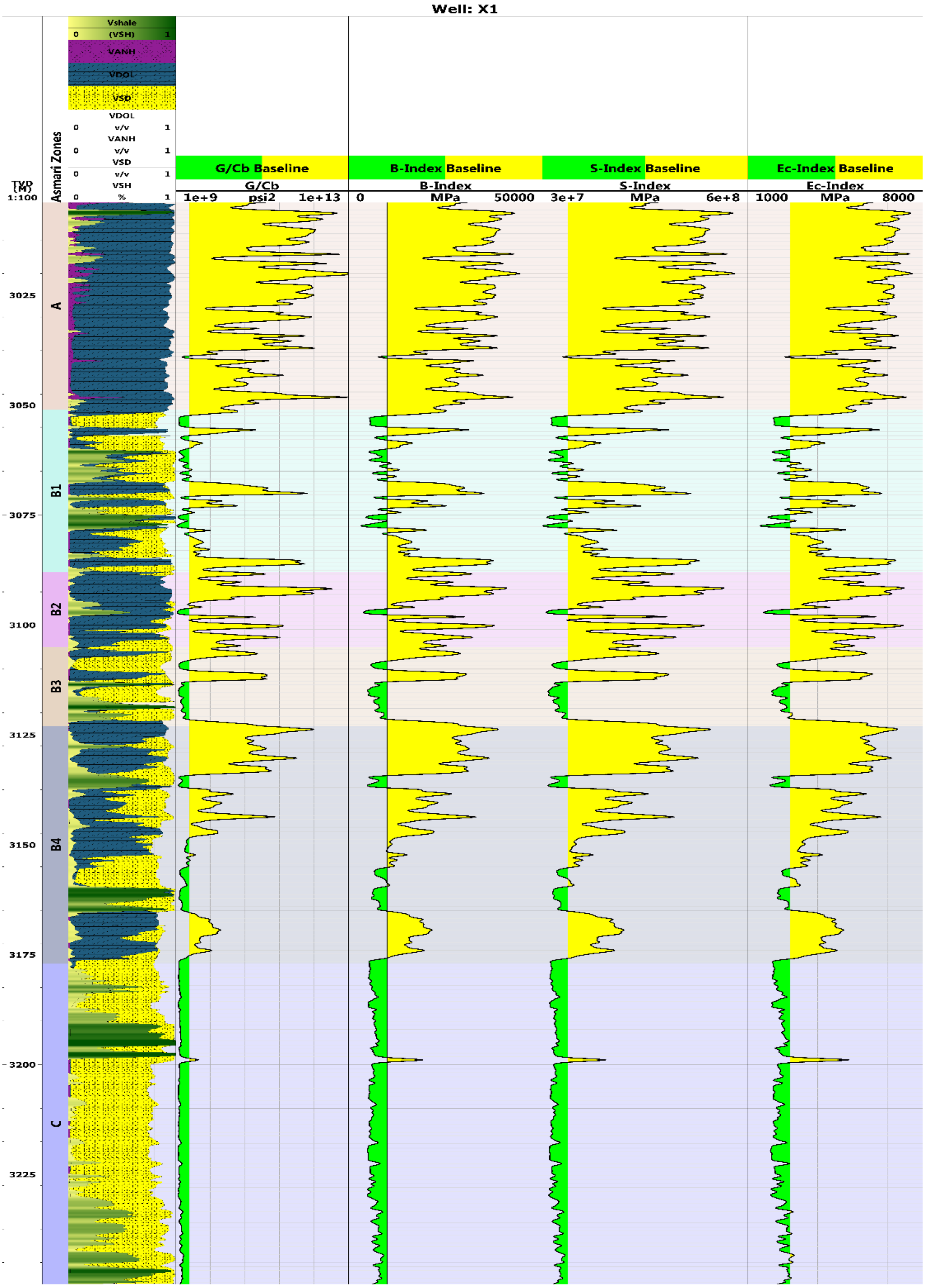

Fig. (3): Sanding intervals prediction by *G/Cb*, *B-Index*, *S-Index*, and *Ec-Index* of X1 well.

Open Access
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Table (1) Critical limits of onset sand production prediction.

Method	Critical Limit of Sanding Onset	Unit
G/Cb	$< 800 \times 10^9$	Psi^2
UCS	< 36	Mpa
PHIT	> 0.2	v/v
CSW	> 80	us/ft
B_{index}	< 10000	Mpa
S_{index}	$< 10^8$	Mpa
E_C	< 2700	Mpa
CDDP	< *CDDP*	psi

The following **Table (2)** is listing sand onset likelihood to produce depths at X1 well based on integrated interpretations among eight methods with lithology tracks. Selecting of these intervals is very important for suggestion best downhole and surface solutions for sand production controlling.

Table (2) Sanding onset problem intervals of X1 well.

X1 Well	
Zone	**Sand Onset Interval (m)**
B1	3052-3057
B1	3078-3079
B2	3095-3098
B3	3017.5-3110.5
B4	31148-3158

4. Conclusions

The current study is dealt with sand production prediction intervals by using eight methods: *CDDP*, *CSW*, *UCS*, *PHIT*, G/C_b, B_{-Index}, S_{-Index}, and $E_{c\text{-}Index}$. One vertical X1 well penetrated Asmari formation at Y oil field is selected for this study. 2462 measured points of *CSW*, *SSW*, and *DL* logs are utilized as a basic for sanding intervals prediction using eight mentioned methods. Lithology is determined for showing rock types at each depth. Sanding is likelihood to produce if declining values of G/C_b, *UCS*, B_{-index}, S_{-index}, and $E_{C\text{-index}}$ curves lower than critical values of these approaches and exceeding values of *PHIT*, and *CSW* curves than critical values of these methods. *CDDP* is calculated for four depletion rates 0%, 15%, 25%, and 35%. If *CDDP* lower than normal trend, it will match with other seven approaches indicating sanding onset intervals, while it is important in selecting best methods for sand production controlling.

Open Access
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Nomenclatures

CDDP = Critical drawdown pressure (psi)

CSW = Compressional sonic wave time (us/ft)

DL = Density log (gm/cc)

E = Youngs modulus (psi)

$E_{c\text{-}Index}$ = Combined index method (Mpa)

G/C_b = Shear modulus to bulk compressibility ratio (psi^2)

G_{dyn} = Dynamic shear modulus (Mpa)

$G_{Ref\text{-}Sand}$ = Reference shear modulus for sandstone (Mpa)

M = Poro-elastic constant (unitless)

PHIT = Total density - neutron porosity (percent)

P_p = Pore pressure (psi)

PR = Poisson ratio (unitless)

S_{Hmax} = Maximum horizontal stress (psi)

S_{hmin} = Minimum horizontal stress (psi)

$S_{\text{-}Index}$ = Schlumberger index method (Mpa)

SSW = Sonic shear wave time (us/ft)

TWC = Thick wall cylinder model (psi)

U = Formation strength (psi)

UCS = Unconfined compressive strength (Mpa)

α = Biot coefficient (unitless)

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