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MULTICRITERIA EVALUATIONS FOR SAND PRODUCTION POTENTIALS: A CASE STUDY FROM A PRODUCING OIL FIELD IN THE NIGER DELTA BASIN (NIGERIA)

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ABSTRACT

Geomechanical evaluation of three wells in an onshore Niger Delta Oil Field in which some reservoirs have histories of free water production was carried out to predict their potential for sand production. The mechanical characteristics of the reservoirs, such as the Poisson ratio (v), shear modulus (G), elastic modulus (E), bulk modulus (Kb), and bulk compressibility, were calculated using petrophysical parameters such as s-velocity (Vs), p-velocity (Vp), gamma ray index (IGR), the volume of shale (Vsh), porosity (), and pseudo factor (q) derived from wireline logs (Cb). Five geomechanical techniques—porosity, acoustic wave travel time, sand production index, Schlumberger sand production index, and shear modulus to bulk compressibility ratio (G/Cb) were used to forecast the potential for sand production in the reservoirs. The porosity values varied from 14 to 27%, which is below the threshold value of 30% for sand production. The acoustic wave travel time ranged from 81.59 to 89.91s/ft, which is below the threshold value of 104s/ft for sand production. The threshold value for the sand production index was $< 2.9 \times 10^6$*psi. The values for the sand production index fell between 11x* 10^6*psi and 12.4 x* 10^6*psi, which is below the limits for the onset of sanding. The G/Cb values in the reservoirs across the three wells fell between 1.15 x* 10^{12}*psi*^{2} *and 1.43 x* 10^{12}*psi*^{2} *while the threshold value for the Schlumberger sand production index fell between 1.15 x* 10^{12}*psi*^{2} *and 1.43 x* 10^{12}*psi*^{2}*. Only the Schlumberger criterion predicted the potential for likely sand production.*

Keywords: Geomechanical, Sand Production, Shear Modulus, Bulk Compressibility, Niger Delta

INTRODUCTION

Sand production has grown to be a significant difficulty in the process of producing crude oil. When a weak reservoir quickly runs dry or malfunctions, oil is produced in small grains the size of sand, which can lead to equipment failure. In young, unconsolidated tertiary formations, sand production occurs frequently.

Sand production may be transient during which sand concentration may decline with time under constant well production conditions or may be continuous where continuous production of sand occurs(Veeken*et al.*, 1991). It becomes catastrophic when a high rate of sand ingress causes wells to cease oil production. This can be a result of slugging or a significant surge of sand. This leads to production problems when the sand grain produced blocks screens, impedes oil flow and eventually contributes to equipment wear. Sanding always leads to added expense to production operations.

Five basic sand issues that are often seen in the field were the subject of investigations by Morita and Boyd in 1991. The first was the sear-type sand issue in an Alaskan sand deposit with weak consolidation. The second was the sands created by water breaking through an intermediate unconsolidated deposit. They concluded that the main reason for sand generation was the reduction of capillary pressure, which held the sand formation together. In the third instance, sand was generated from cemented formations with reservoir pressure depletion in North Sea reservoirs. The fourth kind of sand generation was seen in cemented strata with strong horizontal tectonic stresses in California along the San Andrea fault. The fifth method of sand production, which included many holes with deep perforations, resulted in a high-pressure gradient around the cavity surface.

Osisianya outlined some variables that have contributed to the formation of sand (2010). The formation strength, change in in-situ stresses, and fluid production rate were the most important variables. According to him, the issues brought on by sand influx included erosion and compaction, loss of production due to sand bridging in tubing and/or flow lines, abrasion of downhole tubular/casing, subsurface safety valve, and surface equipment, casing/tubing buckling, failure of casing or liners from the removal of surrounding formation. Additionally, he mentioned how costly and difficult it is to handle and dispose of generated sand, particularly offshore where solids must be collected from surface facilities on platforms and transported to authorized disposal locations.

Output data, well logs, laboratory tests, acoustic, invasive sand monitoring devices, and analogies are some of the techniques used to forecast sand production. The study examines five typical sand production issues that are frequently seen in oil fields, including issues brought on by (1) unconsolidated formations, (2) water breakthrough for weak-to-intermediate unconsolidated formations, (3) reservoir pressure depletion in relatively strong formations, (4) abnormally high lateral tectonic force in relatively consolidated formations, and (5) sudden change in flow rate or high flow rate.

The design of a sand management plan, which is often implemented on a reservoir basis, requires an accurate prediction of the amount of sand that will be produced in a formation. Given the high expense of sand control methods, it is more cost-effective to forecast the likelihood that a formation will produce sand than to wait until it does and then use sand control methods. Determining the kind of sand management method to use requires the capacity to foresee when a reservoir would most likely fail and begin generating sand. New tactics, ranging from prediction to control to management, are always being researched to lessen issues associated with sand production. If a sonic log wasn't available, Enyinla and Oladunjoye (2014) showed that p-wave velocity, porosity, and shale content could be used to estimate the rock mechanical parameters needed to forecast the generation of sand, including the s-wave velocity. Similarly, elastic moduli, which influence the formation's capacity to produce sand, may be used to estimate the combined modulus of strength as well as the ratio of shear modulus to compressibility. With the use of this knowledge, the risk connected with hydrocarbon exploration may be reduced for the protection of workers and machinery as well as for the environment as a whole.

There have been studies on sand prediction and control by authors such as Bellarby (2009), Nouri et al. (2013), Ma Dong et al. (2013), and Khamehchi and Reisi (2015). According to Oluyemi and Oyeneyin (2010), the Hoek and Brown failure criteria may assist in the development of a novel time-coupled analytical failure model for the investigation of sanding potential production in real-time. Data such as elastic modulus and rock strength are needed to successfully mechanically evaluate the geomechanical characteristics of rocks (Farquhar et al, 1994). Although the use of cores to determine geomechanical parameters was said to be the most reliable way. However, it has its limitations (Edlman *et al*, 1998). Fractured or weak rocks are not easy to core for analysis to obtain information at that interval of interest in a formation. As an alternative approach, the use of sonic logs has been adopted for deriving the geomechanical properties of rocks. Due to compressional or tensional forces, rocks tend to be stressed and the response of rocks to stress can essentially be quantified even to the point of failure. This response depends on their strength and moduli. The results of deformational tests may be used to compute the static moduli, while the density of the rocks and the speed of sonic waves can be used to determine the dynamic moduli. Both numbers are equally measurable in the lab, although they are often not the same. Rock density estimated from logs and sonic wave velocity may both be used to compute moduli. According to Walsh and Brace (1966), Jizba and Nur (1990), and Fjaer (1999), the occurrence of fissures in natural rocks, which seemed to lessen the high confining pressures, was the cause of the discrepancy between the static and dynamic moduli.

Well logs, which are most handy for a total unit of the formation, gave a straight measurement of the petrophysical parameters of the formation that were then used to derive the geomechanical properties.Elastic parameters were calculated from Vp/Vs ratio (Potter and Foltinek,1997), and presented as a cross relation to show an easier and quicker approach to Poisson’s ratio prediction and estimation used in defining weakness depth, and apparently, the stability of the borehole and reservoir coherency (Ghawar and Elburas, 2015).

To forecast and assess the sanding potential as well as get practical knowledge of formation and production behaviour, the integration of approaches was suitable. According to Enyinla and Oladunjoye (2014), understanding these elastic moduli allows one to estimate the combined modulus of strength, shear modulus, and compressibility ratio, all of which are important for determining how competent a deposit is at producing sand.

The study area is part of the OMLs 18 and 24 in the Niger Delta basin, situated some 40km southwest of Port Harcourt (**Figure 1**). The lowerAkata Formation, the Agbada Formation, which alternates sandstones and shales, and the top Benin Formation are the three lithostratigraphic divisions of the Niger Delta basin (dominated by shale). The delta complex as a whole is covered by the three lithostratigraphic units, which range in age from the early Tertiary to the recent. The fact that certain reservoirs in the Agbada and upper Akata Formations have been reported to produce sand may be related to the fact that the majority of the sandstones in the delta are almost completely unconsolidated with minimal amounts of argillic-silicic cement (Kulke, 1995). According to reports, a reservoir in the region thought to be the greatest hydrocarbon-bearing produced just 13.7 MMstb of dry oil despite having a predicted ultimate recovery of 52.5 MMstb and experiencing a major water cut-off (Ikomi*et al.*, 2002). According to Chanpura*et al.*, (2013), high water cuts essentially lead to sand production. Hence, it has become imperative to use multicriteria analyses of data derived from wireline logs to attempt the prediction of the limiting values for the onset of sanding in the area, and possibly proffer design control measures.

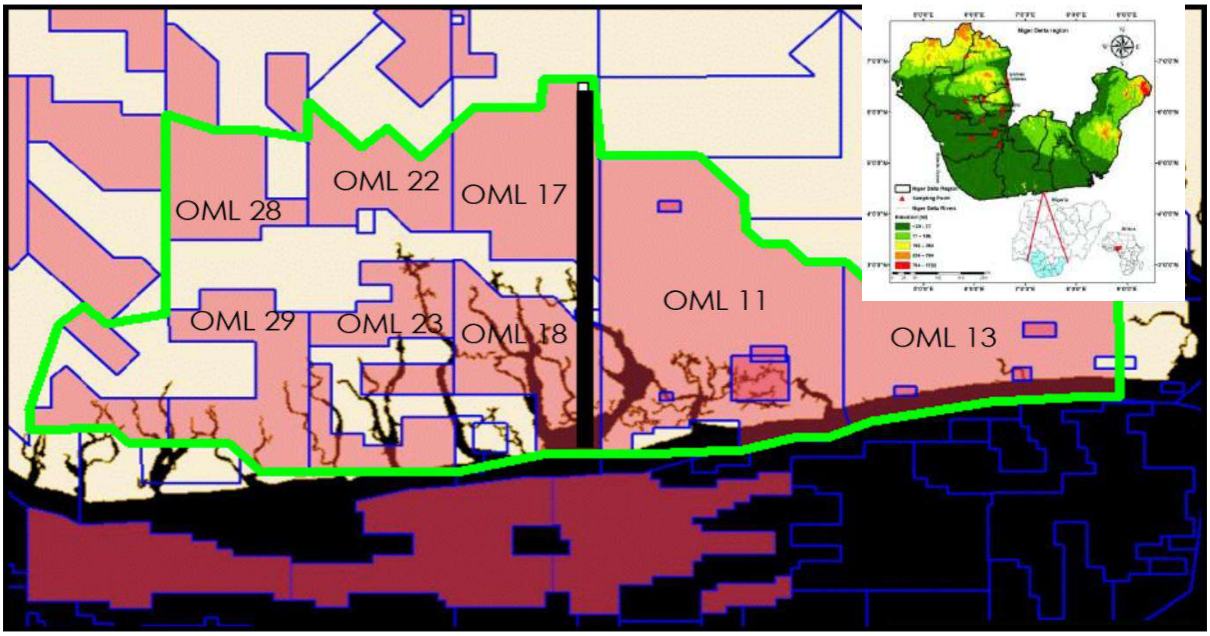

Figure 1: Satellite image of the Niger Delta basin, showing various oil block/concessions information and an index geographic map of Nigeria and the Niger Delta showing the location of the studied field

MATERIALS AND METHODS

For the investigation, four wells comprising wireline logs including gamma-ray, density, acoustic, and deep resistivity logs were employed. Before establishing the stratigraphic connection of the examined reservoirs across the field, the logs were first quality-checked and converted to true vertical depth subsea (TVDSS). Three techniques; the Schlumberger Sand Production Index (S.R), the Shear Modulus to Bulk Compressibility Ratio (G/Cb), and the Sand Production Index were used to determine the potential for sand production across the area (B).

The Schlumberger Sand Production Index (S.R) was determined by using the Dong *et al*., (2013) relationship between shear modulus and bulk density.;

$$S.R = K \times G \qquad (\mathbf{1})$$

Where;

K = Bulk modulus, and
G = Shear modulus

Before determining the Bulk Compressibility Ratio (G/Cb), the bulk modulus (K) was computed using the relationship betweenE, G, and K;

$$K = (3E - 4G)/3 \qquad (\mathbf{2})$$

Where;

E = Elasticity modulus, and
G = Rigidity modulus

The Shear Modulus (G) was estimated using the Schlumberger (1989) equation, thus;

$$G = a\rho_b/\Delta T_S\, v \qquad (\mathbf{3})$$

Where;

Coefficient a = 13464,
ρb= bulk density,
ΔT_S = shear sonic transit time

Thereafter, the G/Cb ratio was derived as shown (Tixier, 1975), thus;

$$G/Cb \qquad (\mathbf{4})$$

Bulk compressibility (Cb) was computed using the equation;

$$Cb = 1/K \qquad (\mathbf{5})$$

In the third method, the sand production index was derived using the equation as shown below (Dong *et al*., 2013);

$$B = E/(3(1-2v)) + 4/3 \times (E/(2(1+v))) \qquad (\mathbf{6})$$

Where;

E = Elasticity modulus, and
v = Poisson's ratio

Young's modulus or Elasticity modulus (E) was computed using the equation;

$E = (\rho \times Vs \times (3Vp^2 - 4Vs^2)) / (Vp^2 - Vs^2)$ (**7**)

Where ρ = Bulk density,

Vs = s-velocity, and
Vp = p-Velocity

To determine Vp and Vs, the sonic compressional time (ΔTc) and the shear transit time (ΔTs) were required from sonic logs. However, the shear Transit time (ΔTs) data was not available for the wells. Thus, ΔTs was computed as recommended by Greenberg and Castanga (1993) using the relationships in equations 8, 9 and 10 as shown below;

$Vp = 304878/\Delta Tc$ (**8**)

$Vs = (0.804 \times Vp) - 0.856)$ (**9**)

$Vs = 10^6 / \Delta Ts$ (**10**)

Where;

Vp = p – Velocity, and
Vs = s – Velocity

The Poisson's ratio (V) was determined using the Dressler Atlas (1982) method as shown below:

$v = 0.125q + 0.27$ (**11**)

Where;

q = pseudo factor (fraction of total porosity occupied by disseminated shale). It shows the producibility of reservoir rocks. The results obtained were compared with standard values to determine the onset of sanding during prediction.

RESULTS AND DISCUSSION

Through well-to-well correlations, five sandstone reservoirs (reservoirs A to E) were delineated (**Figures 1 and 3**) across the field. The dominant lithology derived from the wireline log signatures consisted of sand sequences with subordinate shale beds, which may occur as homogenous units or as heteroliths. The reservoir sands' porosity, which typically ranged between 10 and 40%, was distinguished by a very low to high permeability range of 10 to 100mD. The reservoir sands' geophysical and petrophysical characteristics are shown in Tables 1 and 2, which were created using the correlograms in Figures 4 and 5. The field's potential to produce sand was assessed using the findings.

Schlumberger Sand Production Index Method (S/I)

According to data from Table 3, the reservoirs B, C, and D in well-004 and A, B, C, and D in well-005 have S/I (Schlumberger Sand Production Index) values that are below the level at which sand may be produced, indicating that sanding issues are most likely to occur. This might be supported by the Schlumberger sand production index of a formation smaller than 1.24 1012Psi2, which indicates that sand management measures are required for wells 004 and 005. (Dong et al., 2013). The linear regression analysis involving plots of depths (ft) against sand production index (B) in reservoir-A well-005 indicated weak negative relationships, which implied that sanding is not a function of the depth of a reservoir in the well (Figure 6).

Shear Modulus to Bulk Compressibility Ratio (G/Cb)

Tixier (1975) utilized the G/Cb ratio (shear modulus to bulk compressibility) to forecast the likelihood of sanding in reservoirs. The ratio in this study exceeded the value of 0.8×10^{12} Psiin all the reservoirs (**Table 4**). This is similar to the results of Khamehchi and Reisi (2015) in which the G/Cb ratio did not imply high sand production potential even as the production of free water and high water cut in the wells suggested otherwise. Regression analysis involving plots of depths against the G/Cb (Shear Modulus to Bulk Compressibility) ratio in reservoir A well-005 (**Figure 7**) showed a negative correlation indicating that as depth increased, the Shear Modulus to Bulk Compressibility ratio decreased.

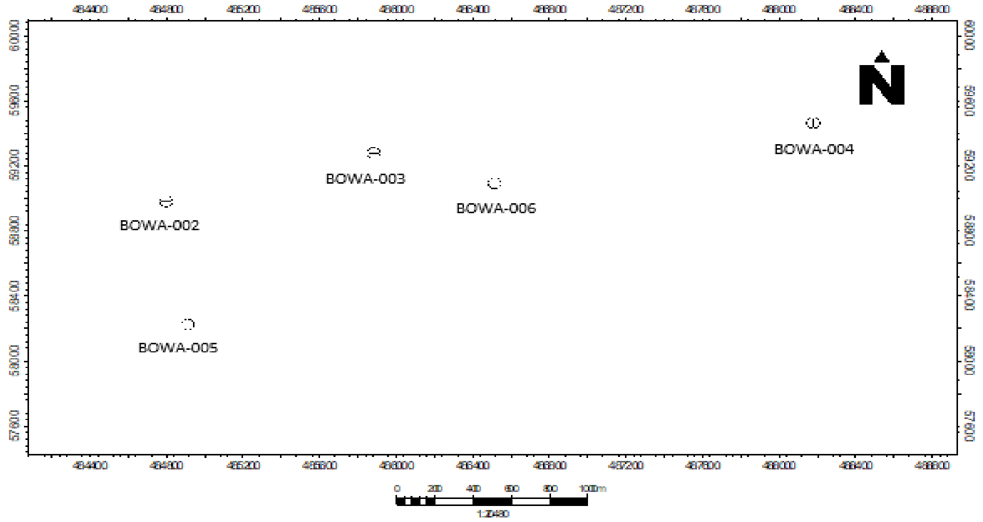

Figure 2: Base map of the study area, showing the spatial distribution of various wells

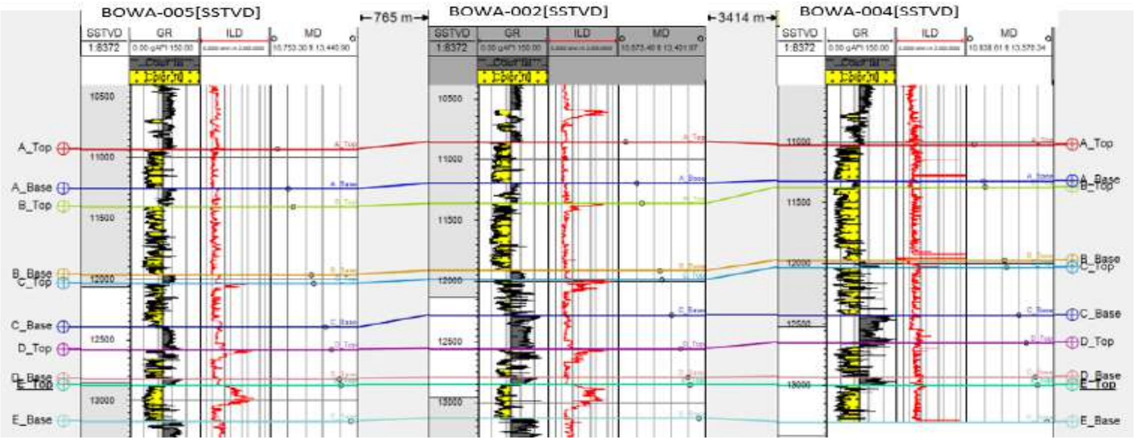

Figure 3: Correlation panel from gamma-ray logs, showing stratigraphic positions of various reservoir sand bodies in wells-005, 002 and 004

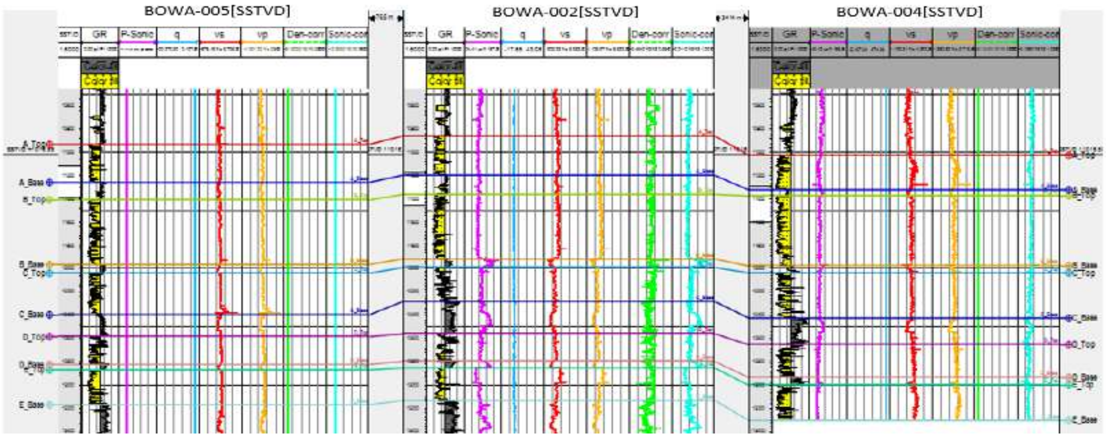

Figure 4: Correlation panel from gamma-ray logs, showing some selected petrophysical properties of various reservoir sand bodies from wells-005, 002 and 004

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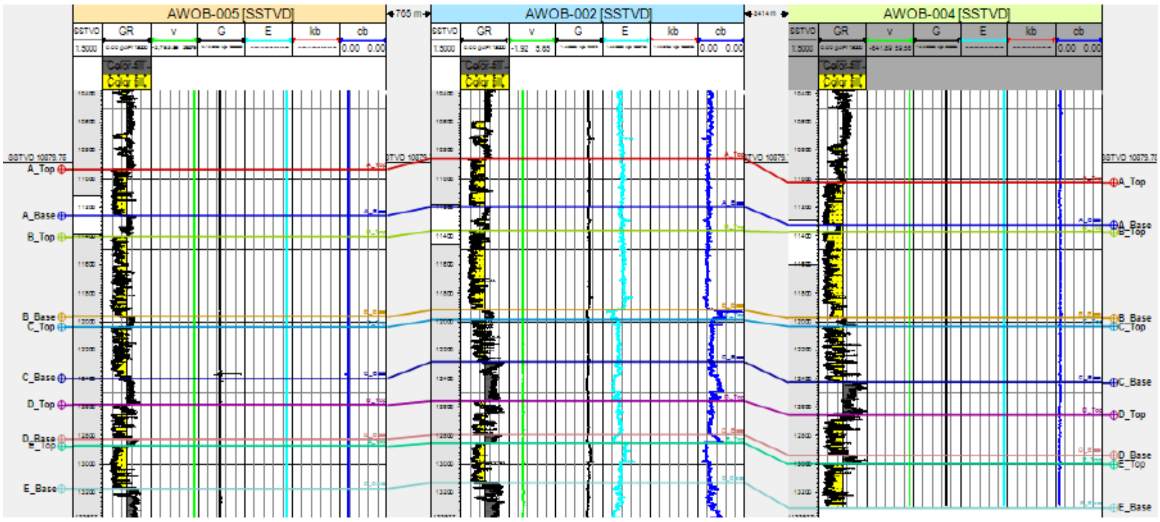


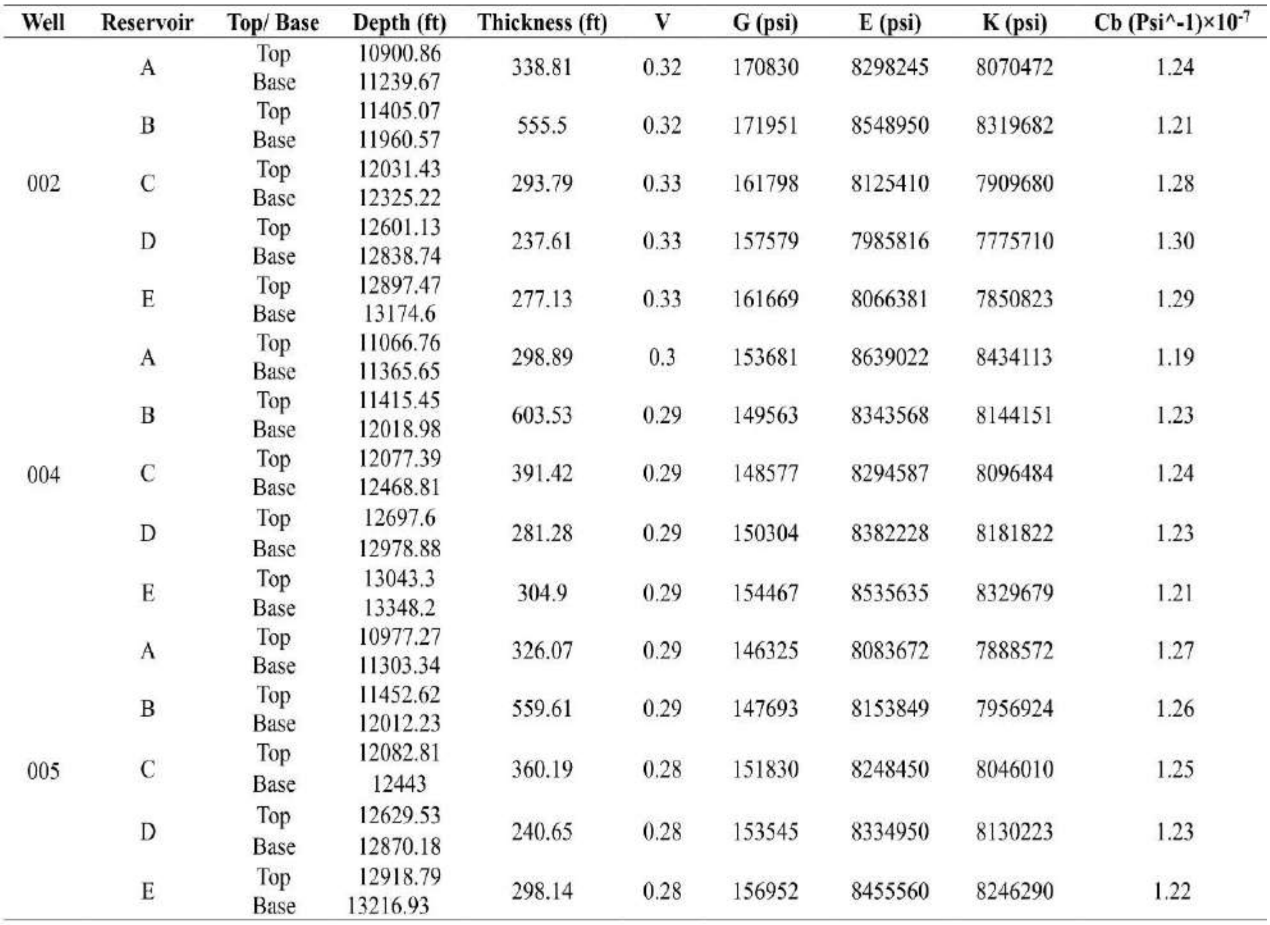
Figure 5: Correlation panel from gamma-ray logs, showing some selected mechanical properties of various reservoir sand bodies from wells-005, 002 and 004

Table 1: Summary of the results of the calculated petrophysical parameters

Well	Reservoir	Top/ Base	Depth (ft)	Thickness (ft)	Vp	Vs	IGR	Vsh	Den-corr	Sonic-corr	Q
002	A	Top Base	10900.86 11239.67	338.81	3571.73	2870.82	0.15	0.04	0.16	0.25	0.37
	B	Top Base	11405.07 11960.57	555.5	3625.63	2914.15	0.15	0.04	0.14	0.24	0.43
	C	Top Base	12031.43 12325.22	293.79	3472.81	2791.28	0.18	0.06	0.14	0.27	0.46
	D	Top Base	12601.13 12838.74	237.61	3419.65	2748.54	0.21	0.07	0.14	0.27	0.27
	E	Top Base	12897.47 13174.6	277.13	3459.86	2780.87	0.21	0.07	0.14	0.27	0.46
004	A	Top Base	11066.76 11365.65	298.89	3750.92	3014.88	0.12	0.03	0.18	0.22	0.2
	B	Top Base	11415.45 12018.98	603.53	3665.93	2946.55	0.13	0.04	0.19	0.24	0.18
	C	Top Base	12077.39 12468.81	391.42	3659.47	2941.36	0.16	0.05	0.19	0.23	0.19
	D	Top Base	12697.6 12978.88	281.28	3692.42	2967.85	0.17	0.06	0.19	0.22	0.22
	E	Top Base	13043.3 13348.2	304.9	3747.52	3012.15	0.17	0.05	0.18	0.23	0.17
005	A	Top Base	10977.27 11303.34	326.07	3588.17	2884.03	0.1	0.02	0.21	0.25	0.16
	B	Top Base	11452.62 12012.23	559.61	3610.94	2902.34	0.11	0.03	0.21	0.25	0.16
	C	Top Base	12082.81 12443	360.19	3655.92	2938.51	0.11	0.03	0.21	0.24	0.11
	D	Top Base	12629.53 12870.18	240.65	3685.46	2962.26	0.11	0.03	0.2	0.23	0.11
	E	Top Base	12918.79 13216.93	298.14	3729.6	2997.74	0.11	0.03	0.2	0.23	0.1

Vp = p-Velocity, Vs = s-Velocity, Vsh = volume of shale, IGR = Gamma Ray Index, Q = Pseudo factor

Table 2: Summary of the results of the calculated Geomechanical parameters



Well	Reservoir	Top/ Base	Depth (ft)	Thickness (ft)	V	G (psi)	E (psi)	K (psi)	Cb (Psi^-1)×10^{-7}
002	A	Top Base	10900.86 11239.67	338.81	0.32	170830	8298245	8070472	1.24
	B	Top Base	11405.07 11960.57	555.5	0.32	171951	8548950	8319682	1.21
	C	Top Base	12031.43 12325.22	293.79	0.33	161798	8125410	7909680	1.28
	D	Top Base	12601.13 12838.74	237.61	0.33	157579	7985816	7775710	1.30
	E	Top Base	12897.47 13174.6	277.13	0.33	161669	8066381	7850823	1.29
004	A	Top Base	11066.76 11365.65	298.89	0.3	153681	8639022	8434113	1.19
	B	Top Base	11415.45 12018.98	603.53	0.29	149563	8343568	8144151	1.23
	C	Top Base	12077.39 12468.81	391.42	0.29	148577	8294587	8096484	1.24
	D	Top Base	12697.6 12978.88	281.28	0.29	150304	8382228	8181822	1.23
	E	Top Base	13043.3 13348.2	304.9	0.29	154467	8535635	8329679	1.21
005	A	Top Base	10977.27 11303.34	326.07	0.29	146325	8083672	7888572	1.27
	B	Top Base	11452.62 12012.23	559.61	0.29	147693	8153849	7956924	1.26
	C	Top Base	12082.81 12443	360.19	0.28	151830	8248450	8046010	1.25
	D	Top Base	12629.53 12870.18	240.65	0.28	153545	8334950	8130223	1.23
	E	Top Base	12918.79 13216.93	298.14	0.28	156952	8455560	8246290	1.22

V = Poisson's ratio, G = Shear modulus, E = Elasticity modulus, K = Bulk modulus, Cb = Bulk compressibility

Table 3: Schlumberger Sand Production Index(S/I) values of reservoirs across wells

	Reservoirs A	**Reservoirs B**	**Reservoirs C**	**Reservoirs D**	**Reservoirs E**
Parameter	S/I×10^{12} Psi^2	S/I×10^{12} Psi^2	S/I×10^{12} Psi^2	S/I×10^{12} Psi^2	S/I×10^{12} Psi^2
Well-002	1.38	1.43	1.29	1.24	1.29
Well-004	1.31	1.22	1.20	1.23	1.29
Well-005	1.15	1.18	1.18	1.22	1.27
Average	**1.28**	**1.28**	**122**	**1.23**	**1.28**

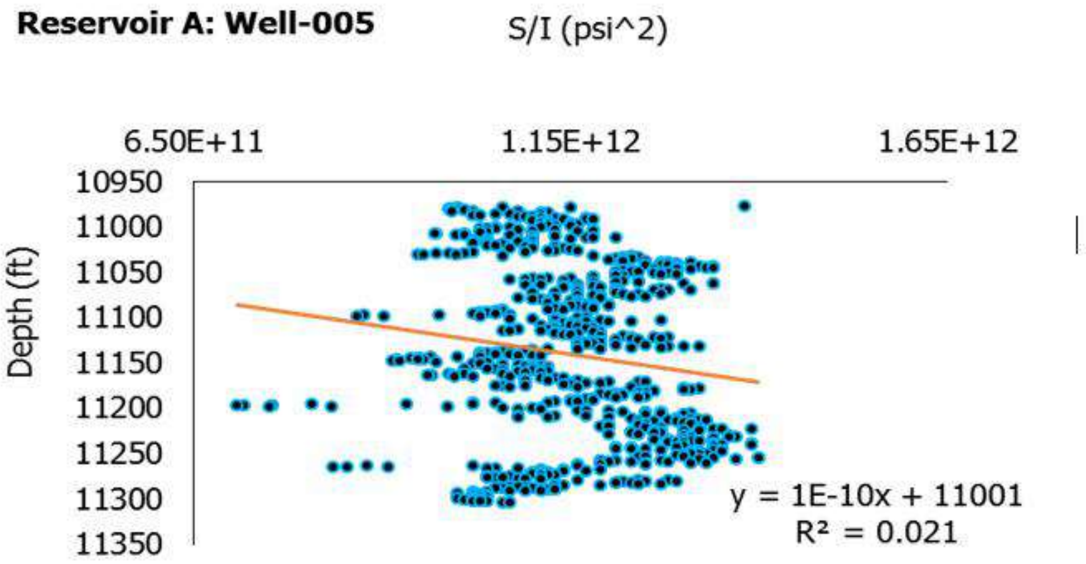


Figure 6: Linear regression analysis, showing a cross plot ofSchlumberger sand production index against depth in reservoir A well-005

Table 4: Shear Modulus to Bulk Compressibility Ratio (G/Cb) of reservoirs across the wells

	Reservoirs A	Reservoirs B	Reservoirs C	Reservoirs D	Reservoirs E
	G/Cb×10^{12} Psi^2	G/Cb×10^{12} Psi^2	G/Cb×10^{12} Psi^2	G/Cb×10^{12} Psi^2	G/Cb×10^{12} Psi^2
Well-002	1.38	1.43	1.29	1.24	1.29
Well-004	1.31	1.22	1.20	1.23	1.29
Well-005	1.15	1.18	1.18	1.22	1.27
Average	**1.28**	**1.28**	**1.22**	**1.23**	**1.28**

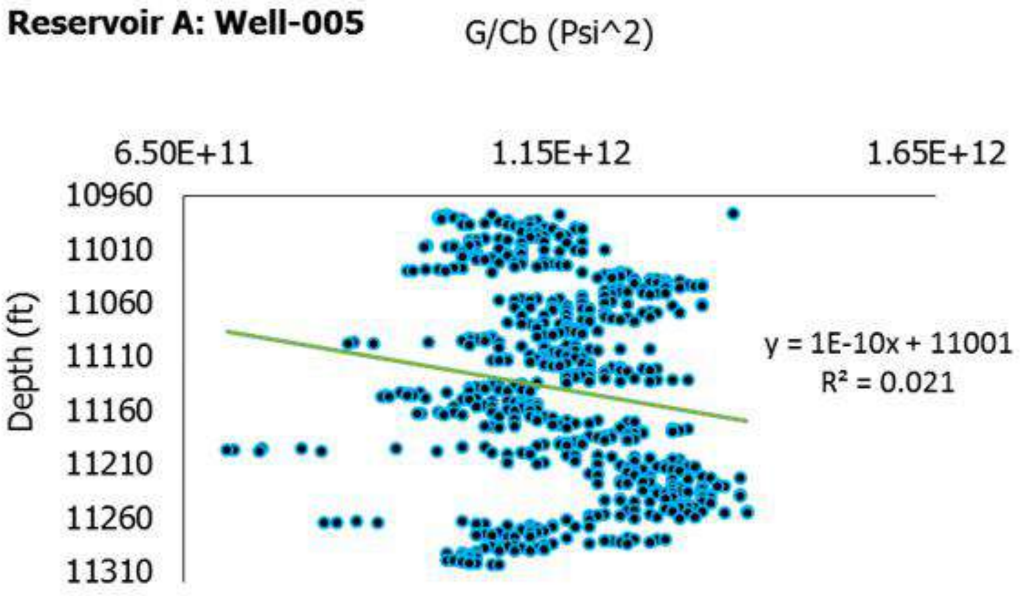


Figure 7: Linear regression analysis, showing Shear Modulus to Bulk Compressibility Ratio against depth in reservoir A well-005

Sand Production Index (B)

All the reservoirs evaluated from the field (Table 5) have sand production index values ranging from 1.26 x 10^{-7} Psi to 1.10 x 10^{-7} Psi with well-005 giving the least value among all the reservoirs, thus, requiring sand control measure. Dong et al. (2013) state that control methods become imperative when the sand output index is less than 2.9 106 Psi.

Porosity

All the reservoirs evaluated from the field (Table 6) have porosity values of less than 30%. According to Penberthy and Shaughnessy (1992), if the porosity of a reservoir is higher than 30%, the formation will most likely produce sand. These porosity values, however, implied consolidation and the absence of sanding potential. Nevertheless, the porosity of a formation can also be used to infer the likelihood of sand production. Due to a lack of matrix cementation, a formation may have a high porosity value. In other words, porosity has a negative relationship with density. The higher the porosity, the lower the density, and the lower the strength.

Acoustic Wave Travel Time (ΔTc)

The potential for sand generation in these wells was also investigated using the acoustic wave travel time criteria. The porosity and strength of the formation are connected to the acoustic travel time. According to statistics published by Dong et al. (2013), the formation will create sand if the sonic compressive time is more than 104 microseconds per foot when using the acoustic travel time approach. As shown in Table 7, the acoustic travel durations in reservoirs A to E throughout the three wells are all below the sand-producibility criterion of 104 microseconds per foot.

Table 5: Average Sand Production Index (B) of reservoirs across wells

Wells /Reservoirs	**A**	**B**	**C**	**D**	**E**
	B(10^{-7}Psi)	B(10^{-7}Psi)	B(10^{-B7}Psi)	B(10^{-7}Psi)	B(10^{-7}Psi)
Well-002	1.20	1.26	1.22	1.22	1.21
Well-004	1.16	1.12	1.22	1.24	1.21
Well-005	1.10	1.10	1.11	1.12	1.13

Table 6: Average porosity of reservoirs across the wells

Wells / Reservoirs	**Porosity ϕ (%)**	**A**	**B**	**C**	**D**	**E**
Well-002	Density(ϕ)	0.16	0.14	0.14	0.14	0.14
	sonic(ϕ)	0.25	0.24	0.27	0.27	0.27
Well-004	Density(ϕ)	0.18	0.19	0.19	0.19	0.18
	sonic(ϕ)	0.24	0.23	0.23	0.22	0.23
Well-005	Density(ϕ)	0.21	0.21	0.21	0.2	0.2
	sonic(ϕ)	0.25	0.24	0.24	0.23	0.23

Acoustic Wave Travel Time (ΔTc)

Table 7: Average Acoustic Travel (DTc) Time in reservoirs across wells

Wells / Reservoirs	**A** **ΔTc(μs/ft)**	**B** **ΔTc(μs/ft)**	**C** **ΔTc(μs/ft)**	**D** **ΔTc(μs/ft)**	**E** **ΔTc(μs/ft)**
Well-002	85.44	84.23	88.5	89.91	88.97
Well-004	81.59	83.31	83.47	82.74	81.61
Well-005	85.07	84.55	83.67	83.00	82.04

DISCUSSION

Sand production is likely to occur in the Niger Delta in unconsolidated tertiary reservoir rocks. The phenomenon increases proportionately to water cuts. Generally, the strength of sand is controlled by the cohesive and frictional forces that exist between grains. When water is present, the grains are covered by the liquid, but the surface tension of the water's syn-depositional connate, which surrounds the sand particle, gives the grains their cohesiveness. By adding more water during the sand-making process, the forces that create surface tension are lessened. This, in turn, lessens the forces that induce sand cohesiveness by lubricating the grain-to-grain contact.

The original strength of soils is borne by solid particles only. However, the introduction of water leads to the total stress principle where both the water and solid phases contribute to strength. Mohr’s circles of such materials show strength parameters that are less than the effective stress condition. Water lubricates the grain contacts, and reduces the frictional forces between them, leading to slippage and detachment of the sand particles which are transported out of reservoirs during oil production. This idea is comparable to that put out by Robertson and Fear (1997) who hypothesized that sand liquefaction, which occurs when saturated sand loses cohesiveness and interparticle friction reaction to dynamic stress, may play a role in the formation of sand. The research indicated that due of the decrease of grain consistency during liquefaction, sand particles flow readily like a liquid.

This causes sand to migrate at the grain level in the formation around a hole or to mobilize and detach sand particles and/or aggregates in the failed rock as a consequence of the hydrodynamic force of the generating fluids. In this water-saturated state, low Young’s modulus alters the mechanical strength of the sandstone reservoirs. Similarly, if the sandstone reservoirs contain authigenic (2:1) clay minerals, large volume changes due to swelling and shrinkage can occur when clays come into contact with water, which initiates sand production.

It has also been suggested that oil and water relative permeability impacts sand production (Wu *et al.*, 2006 & Zhanh *et al*., 2020). Earth materials are naturally a three-phase system comprising solid particle-water-air phases. The presence of oil introduces a fourth phase. During production, an increase in water cut is inversely proportional to oil permeability. As a result, the differential pressure needed to produce oil at the same rate increases as well as the stresses in the well bore, especially the shear stress which causes deformation. The shear stresses induce disaggregation of the sand leading to its eventual production.

CONCLUSION

Understanding the circumstances that led to sanding is crucial to giving technical assistance for decision-making on sand management. A multi-criteria approach was used in the research to investigate the possibility of sanding in five wells. It was done because sand production is a significant issue in the Niger Delta and anywhere else that hydrocarbon is generated. The Niger Delta reservoir sands are often unconsolidated, which is a potential sand-producing factor. The research discovered that the data from porosity, acoustic travel time, and sand production index (B) methodologies did not suggest that sand production was possible.

Except the S/I method which predicted the occurrence of the phenomenon in 3 to 4 reservoirs from two of the five wells studied. The mechanism for sand production was mainly the increased water cut which significantly reduced the strength of the rocks by weakening the intergranular cementation. This translated into a reduction in the mechanical cohesion between the sediments when the stresses in the well bore substantially increased, eventually causing the detachment of the grains and sanding.

Our observation is that serious water cuts do not necessarily indicate the possibility of sand production e.g., in well 002. It is concluded that the values of these sand-prone reservoirs in wells 004 and 005 were marginally close to the threshold values for sanding. Therefore, there must be contingency plans for sand control measures in these wells. It is recommended different that methods should be used to increase the chances of identifying sanding potentials that may have been missed by the use of a stand-alone criterion. The findings of this research will make it easier to use decision-making techniques for sand control in comparable situations.

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