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Evaluation of Geomechanical Parameters for Sand Prediction in Apogee Field Offshore, Niger Delta.

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ABSTRACT

The research focuses on the evaluation of geomechanical parameters for sand prediction in APOGEE, offshore Nigeria. Depletion of reservoir, increased water- cut, reservoir ageing, poor completion and poor reservoir management all causes sand production. Sand production increases the cost of maintenance of a well, leads to well shut in and jeopardizes the safety of worker. Four wells were evaluated using geomechanical parameters and well logs data (sonic log, Gamma ray, density, resistivity, and neutron log). Furthermore, six reservoirs were identified (reservoir 1- 6) and correlated across the five wells. Shear and compressive wave travel time from the sonic log were obtained and were used to estimate geomechanical parameters (both elastic and inelastic). The estimated geomehcanical parameters includes Poison ratio, Young modulus, Bulk modulus, UCS and pore pressure. Four methods were used to evaluate the sand potential and they include: B-index, Schlumberger index, Bulk modulus, Compression ratio and combined ratio. The analysis revealed a strong linear relationship between UCS and porosity with a regression coefficient correlation between 1 and 0. 98. This research shows the studied reservoirs falls below the threshold pressure for sand production. Comparing the four methods, the ratio of Shear modulus to the bulk compressibility ratio (G/C_b) method predicted the highest potential for sand production. This research therefore validates that reservoirs in APOGEE field is highly unconsolidated.

Keywords: Poison ratio, Young modulus, Bulk modulus, UCS and Pore pressure and Sand control

1.0 INTRODUCTION

This study focuses on the evaluation of geomechanics parameters for sand prediction, knowing that geomechanics properties have direct relationship with the strength of the formation. Using geomechanics parameters in predicting sand production is very important in completion design plan, well instability plane, drilling program, perforation strategy, reservoir management, well intervention and maintenance. Sample can be gotten from the depth of interest to obtain the geomechanics parameters at specific depth of interest which is refer as direct core measurements. Direct core measurement is best and accurate method of evaluating geomechnainic parameters, but core is expensive, time consuming and it does not cover large area of interest. The calibration of geomechanical properties with previous core measurement with well log data has been introduced. The evaluation of geophysical parameters is important to solve time and expensive core measurement, it also serves guild to new field. Therefore, we can model correct Petrophysical data from the well (well log data). Well logging tools like neutron-density, acoustic velocities. Equation of homogeneous isotropic and elastic rock can con wire-measurements to geomechanical properties.

1.1 Statement of Problems

The life cycle of a well permits productivity long or short term is always determined by the effect of sand production and sand management on the well. Some of the factors includes; sand production, surface equipment, collapse of the formation and loss in revenue accumulation down hole and the erosion of down hole are the major effect of sand influx. Surface equipment such as separators, manifold, flow line, choke when filled or abraded by sand, the well will be shut in to enable the removed of the sand from the equipment. The erosion important surface equipment such as; valves, chokes Christmas tree and treated erosion can cause spillage, loss of equipment that is hazardous to human and the environment. Subsurface tool like screen selective nipple, tubing seal blast joint, parker, casing and tubing can erode due high sand production. Equipment abrasion can also lead to leakage of down hole equipment and other associated problem.

A sand bridge is one of effect of sand production, bridges obstruct the flow fluid from the well to the surface, and the plugs must be removed from normal production to be restored. Washing with smaller diameter concentric tubing strings use to restore normal production. Casing and liner failure of disadvantages of sand production, when casing bearing formation slump due to sand production, as a result of these abnormal load the casing and liner may buckle and a possible loss of the well. Loss of production is vital reason proper sand control and management, if sand production is not proper manage, production may be loss, when a well sand up, the formation damage. This formation damage may reduce porosity and permeability resulting in decrease in the rate of production. This has great effect on the productivity and economic of the entire field. The well control can be loss due to sand production, for instance Christmas tree component are severally eroded, it will be problematic to gain proper control of the well

2.0 LITERATURE REVIEW

2.1 Sand Production

In upstream sector, during planning for production and completion, it important for that the completion or the production engineer to know detail information about the formation or field. One of vital information is have knowledge when the reservoir will produce sand at certain draw down pressure or not under what situations a well produces sand. Core date analysis of sieve size to know the type in order to sand control mechanism will be required. Sand prediction model its importance, to design to have optimum productivity, safety of the well and human. Sand prediction and studies is regularly carried out at the early stage of reservoir field development in order to plan completion drilling program. Sand prediction is important in order proper well completion design and reservoir management strategy and
well intervention plan of well.

Several sand predictions have been built well test, drawdown pressure, porosity log, sonic log analogy and other techniques.

According to Volonte et al. (2013) and Tanaykhin et at (2014), predicting the onset of sanding is a geomechanical concern several methods obtainable can be categorized into three;

i. The first approach is built base on empirical correlation between the onset of sanding and some petropysical parameters that describe either the geomechanical properties of the rock (P- wave transit time) this type and method employed depend on specific laboratory tests.
ii. The second group includes is building analytical models that compare the critical conditions for the sand production onset will produced and the stress on the gain. Analytical method involve evaluation the stress state near the wellbore and perforations by using correlated formulation. These equations are formulated by using geometry of the problem and the geomechanical properties of the rock

iii. Numerical model is most complicated and powerful tool to predict sand production that involved the analysis of all the physical phenomena throughout the life cycle of the well, and with the preferred level of detail. 3D numerical model such as finite element and the finite-difference.

Several researches have been carried out to support out over the in trying to develop methods for predicting sand production. Sand production is good is done in early life of the well, in order to plan for well completion and drilling programme. In predicting sand production, it is vital to determine the strength of the formation, drawdown and reservoir pressure, sand production is direct relation with the strength of the formation (Wilson et al, 2002). The development a model that will detect sand failure and zone where sand will be produced is importance and key to production optimization, sand control, management and ideal well completion design plan (Chin and Ramos, 2002).

Sand production has a lot of disadvantage ranges from economics and safety hazards to well erosion, surface equipment; on these base sand productions pay special attention in the oil and gas industry. Reason why sand production should take serious, erosion of downhole and surface equipment, casing blockage and leakage, casing collapse, reduction in rate of production. Sand production can also result in increased intervention costs, increased shut-in time and other environment issues accompanying with sand disposal mostly in offshore and swamp settings where contamination of water body is key issue. (Osisanya, 2010). The proper understanding of sand production mechanisms with aid in ability to predict and manage sand production. Knowing rate of sand production is beneficial factor for planning and design. It is important to predict the sand potential of a formation, the frequency of sand produced, quantity and particle size distribution of sand and transported through the wellbore to the well, from the well to the surface facilities. Management of sand production and control requires a good knowledge of "if the formation will fail, what time the formation will fail and how much sand will be produced from such failure" (Oyeneyin, 2014). Chang et al. (2006) compiled some empirical correlations that relate formation strength and physical properties in sedimentary rocks. This work extends the Chang et al (2006) methodology to the Niger Delta.

2.2 CAUSES OF SAND PRODUCTION

There are several factors that cause sand production from a formation. Rock strength effect and fluid flow effects can be categorized as the factor influencing the tendency of a formation to produce. These factors include:

I. Level of consolidation, consolidation formation has the tendency to produced sand. Depth has a role to play in term of consolidation, consolidation increase with depth.
II. Rate of production can result to high sand production; if the rate of production is high more sand will produced. Fluid flow from the reservoir when there is pressure differential, also frictional drag force of the fluid should be more the formation strength.
III. Pore pressure decline: pore pressure refers to constant drop in reservoir pressure of the reservoir due to aging. As the reservoir age the reservoir pressure drop giving rise to large amount of stress on the rock.
IV. Fluid velocity: There is direct relationship between the frictional force and flow velocity of the reservoir, if the velocity is increase, the stress on the grain will also increase due to frictional force on the grain. Sand production is experience when there is high frictional fore curse by high velocity above the threshold pressure.

3.0 METHODOLOGY

Parameters		Equations
Compressive (Vp) and shear waves (Vs)	OGAGARUE(2008) Provide relationship between Vp and Vs for Niger Delta	$Vp = 1000000 \times 0.305 \, {}^{\wedge}t_p$ $Vs = 1000000 \times 0.305 \, {}^{\wedge}t_s$
kUniaxial compressive strength (USC)	According to Mc Nally (1987) proposed an equation for kr both consolidated and unconsolidated sandstone. Porosity was determined using sonic log	$USC = 1200\, e^{-0.36 \wedge t}$
Porosity and effective porosity	Porosity was determined using sonic log	$\Phi = \frac{\Delta t_c - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}$
Frictional angle for sandstones	(According Weingarten and parkins,1995)	$\varphi = 57.8 - 105\Phi$
Poission's ratio:		$\mu = \frac{½(\Delta ts \Delta tc)2-1}{(\Delta ts \Delta tc)2-1}$

Calculating the Sand Potential	Sand production will occur if the ratio between Shear Modulus (G) and Bulk Compressibility (CB) become less than $(7 \times 10^{11})\ psi^2$ (Tixier et al, 1975	$G = 1.3 \times 10^{10pb\Delta ts2}$ K = 1.34 × 10^{10} ×pb (1/Δtc^2 - 1/Δts^2 CB = 1/k(b3.2)
B-Index Calculation	Sand production will most likely occur If the estimated B-Index is less than (2×10^4) Mpa (Oilfield ,2013'):.	B = (Ed(3 ×(1-vd) + 34 + ((Ed2×(1-vd) $Edynamic$= ρb×Δ(3Δtc^2-4$\Delta ts^2 \Delta tc^2$-Δts^2 Vdynamic = $\frac{2\times(\Delta tc2-\Delta ts2)}{2\times(\Delta tc2-\Delta ts2)}$
Loading Factor		$LF=\frac{\sigma t2-Pwf}{u}$ Where: $\sigma t2$ is the max. tangential total stress acting on the formation
Fluid Flow Effects	Hoven et al and Tariq,	$\beta=\frac{2.65E10}{k1.2}$ $Re=1.31735E-12*\frac{K\beta\rho v}{u}$ β represent the non-Darcy flow coefficient (dimensions of ft-1);

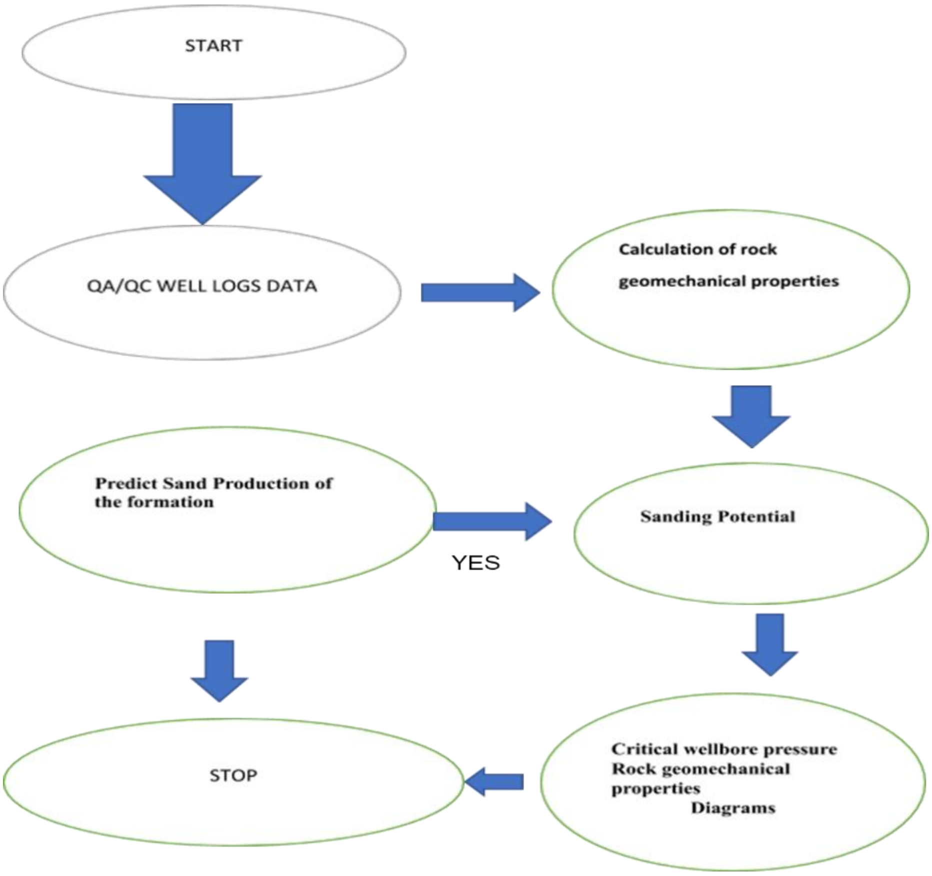

Fig1.1 Flow Chart showing the geomechanical model.

3.1 DATA QUALITY CHECK

In order to achieve the purposes of this study, quality control and quality assurance was done on the available well logging data. Evaluation well log data, such as sonic log, gamma ray log was done, and the required field parameters were calculated and used to predict sand potential.

3.2 LITHOLOGY

Gama ray log data, density- neutron log, sonic log where used in identification of six reservoirs across the four wells. Tops and bases of each reservoir were also determined.

3.3 CALCULATION OF ROCK PROPERTIES

Calculations of both elastic and elastic were done from using available empirical correlations. Sonic and density logs were the primary logs used for this.

Table 1.1 show parameters and equation used in the model

4.0 RESULT AND DISCUSSION

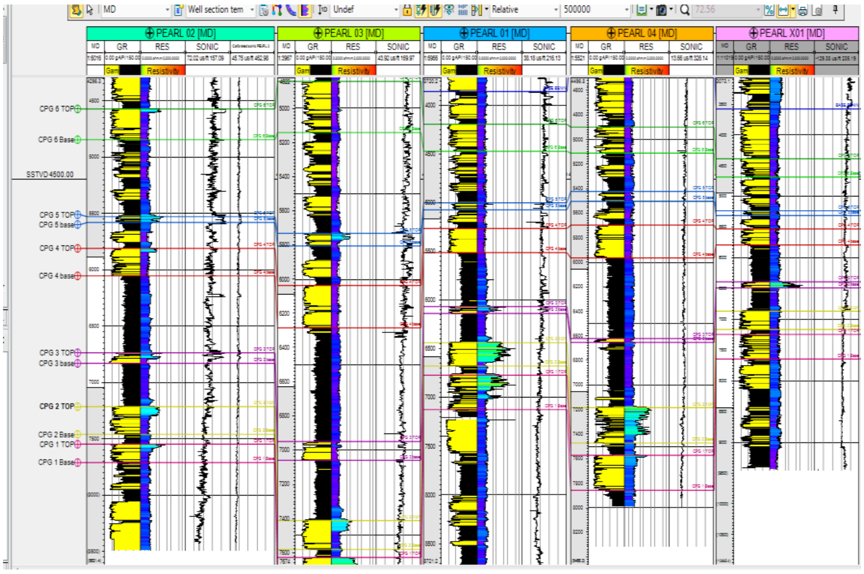

figure 4.1: Well logs showing delineated horizon of the studied reservoir using gamma log

1	PPG	max H	Biot con:	min H S	Vdynami	Edynami	B-INDE	Slb-INDI	CDPc	CDPo	G*K	Overburden stres	Pc	Pwc	Result@G*k
2	4571.588	5450.172	1.311755	2187.199	0.393901	2612.559	4303.265	1346497	6.10616	12.21232	2.721E+11	4611.684	85.08901		SAND PROBLEM
3	4568.299	5450.822	1.3233	2187.498	0.38966	2536.703	4149.288	1264468	6.571166	13.14233	2.9815E+11	4612.234	85.09021		SAND PROBLEM
4	4557.654	5451.472	1.353794	2187.797	0.378579	2356.767	3786.226	1080599	7.928527	15.85705	3.7609E+11	4612.784	85.09142		SAND PROBLEM
5	4540.679	5452.122	1.394619	2188.095	0.364031	2152.932	3379.635	890531.1	10.07051	20.14103	5.0427E+11	4613.334	85.09262		SAND PROBLEM
6	4520.278	5452.772	1.436063	2188.394	0.349612	1978.673	3037.224	743387.7	12.68005	25.36009	6.6823E+11	4613.884	85.09382		SAND PROBLEM
7	4486.086	5453.422	1.49361	2188.693	0.330187	1776.462	2647.756	590329.1	17.15888	34.31777	9.6793E+11	4614.434	85.09502		NORMAL
8	4467.119	5454.072	1.52173	2188.992	0.32095	1690.534	2485.407	531016.9	19.76465	39.52931	1.1524E+12	4614.984	85.09622		NORMAL
9	4468.655	5454.722	1.52034	2189.29	0.321402	1694.612	2493.063	533754.6	19.62887	39.25773	1.1426E+12	4615.534	85.09743		NORMAL
10	4491.936	5455.372	1.487142	2189.589	0.332335	1797.302	2687.437	605227.9	16.60049	33.20097	9.2935E+11	4616.084	85.09863		NORMAL
11	4505.433	5456.022	1.466511	2189.888	0.339247	1866.773	2820.513	656344.8	14.91555	29.83109	8.1502E+11	4616.634	85.09983		NORMAL
12	4523.005	5456.672	1.43699	2190.186	0.349293	1975.084	3030.231	740505.1	12.74393	25.48786	6.7235E+11	4617.184	85.10103		SAND PROBLEM
13	4516.453	5457.322	1.449649	2190.485	0.344963	1927.252	2937.299	702667.3	13.64209	27.28418	7.3071E+11	4617.734	85.10223		SAND PROBLEM
14	4513.641	5457.972	1.455437	2190.784	0.342994	1906.092	2896.345	686267.1	14.06908	28.13816	7.5878E+11	4618.284	85.10343		SAND PROBLEM
15	4513.607	5458.622	1.456413	2191.083	0.342663	1902.567	2889.531	683554.9	14.1421	28.28421	7.636E+11	4618.834	85.10463		SAND PROBLEM
16	4513.878	5459.272	1.456867	2191.381	0.342509	1900.932	2886.372	682299.1	14.17615	28.35231	7.6585E+11	4619.384	85.10584		SAND PROBLEM
17	4515.638	5459.922	1.454779	2191.68	0.343218	1908.477	2900.956	688105.4	14.01999	28.03998	7.5554E+11	4619.934	85.10704		SAND PROBLEM
18	4514.084	5460.572	1.458343	2191.979	0.342009	1895.63	2876.133	678235.5	14.28738	28.57477	7.7321E+11	4620.484	85.10824		SAND PROBLEM
19	4512.75	5461.222	1.461493	2192.278	0.340942	1884.405	2854.475	669674.5	14.5271	29.0542	7.8911E+11	4621.034	85.10944		SAND PROBLEM
20	4509.624	5461.872	1.467563	2192.576	0.338893	1863.116	2813.479	653598.3	14.99798	29.99596	8.2055E+11	4621.584	85.11064		NORMAL
21	4507.46	5462.522	1.471959	2192.875	0.337413	1847.967	2784.371	642286.6	15.34655	30.6931	8.4397E+11	4622.134	85.11184		NORMAL
22	4504.694	5463.172	1.477248	2193.174	0.335639	1830.03	2749.98	629030.7	15.7745	31.549	8.7292E+11	4622.684	85.11304		NORMAL

Fig3.1 display result from Apogee Model

4.1 Porosity, Depth and UCS Relationship

From the analysis the reservoir intervals showed porosity > 31% and this is suggestive that there is likelihood of occurrences of high sand production in this (field) since the associated depth is less than 10000ft, as show in the table 4.3 above.

The analysis shows a good relationship between Poisson ratio and porosity, implying that with a known of porosity value an associated Poisson ratio can be estimated. Porosity, depth, grain size, choke size and strength of the formation are factoring that control sand production. Formation with porosity values higher that 0.32 are most likely potential sand producers. In other word, there is a partially linear relationship between sand production and porosity. Generally, porosity and uniaxial Formation strength increases with depth. From the graph the R^2 value is between 0.97-1.0, indicating good correlation.

4.2 Relationship between Geomechanical Parameters, Rock Strength and Properties with Depth

The first three reservoirs are less compacted compared to the last three reservoir indicating compaction increases with depth. This suggests that the last reservoir has high value of young modulus when compared to reservoir 1and 2. The graph of unconfined compression strength were also studied against petro physical parameters (porosity and acoustic travel time) and the result confirms that UCS is a function of porosity and acoustic travel time. There is an indication of increase in elastic and inelastic properties with depth as shown in Figure above, this happen as a result of compaction due to overburden pressure lower than effective stress conditions. This can cause fluids discharge, rise in grain contacts, increase in Biot‟s coefficient and overall Formation density increments.

4.3 Sand Production Prediction and Critical Drawdown Pressure

Critical drawdown Pressure was calculated using geomechanical parameters. This was done to generate the prediction of sanding parameters as well as the critical drawdown pressure of the studied reservoir. Geomechanical parameters such as elastic moduli and rock strength are needed in order to have an effective geomechanical evaluation of rocks wellbore instability.

4.4 Prediction of Sand Production Potential

To predict sand potential in APOGEE field, five methods were used. Which include; Schlumberger-index, B-index, the ratio of Shear modulus to Bulk compressibility and combined modulus method were calculated from geomechanical parameters of all four wells across.

4.5 Shear modulus to Bulk compressibility ratio (G/C_b)

Shear modulus to Bulk compressibility was used for prediction of sanding across the four wells from reservoir (1-6) , from the study the value of G/C_b fell between $0.61\times10^{12}psi^2$ and $4.1 \times10^{12}psi^2$ with an overall average of $2.73\times10^{12}psi^2$. this empirical correlation implied that a threshold for sanding existed at $G/C_b= 0.8\times10^{12}$ psi^2 whereas values less than $0.8\times10^{12}psi^2$ suggest a high probability of sanding. However, in reservoir six it shows high compaction compare to reservoir one.

4.6 Sand production index (B) method

This has its values between 2.08×10^6 psi^2 and 2.98×10^6 psi^2 as shown in Table 2 with an overall average of 0.37×10^6 psi^2 When the sand production index (*B)* increases, it indicates that the rock elastic modulus is high, thus rock is stiffer and has good stability. When *B* is less than 2.0×10^6 psi^2, exploitation will produce the high reservoir sand.

4.7 Schlumberger sand production index Method (S/I)

From Table 2 the values ranges between $0.98\times10^{12}psi^2$ and $1,53\times10^{12}psi^2$ with an average of $1.19\times10^{12}psi^2$.When the Schlumberger sand production index of a formation is less than $1.24\times10^{12}psi^2$ the formation is likely to produce sand and sand control may be necessary

4.8 Elastic combined modulus (E_c)

In this method, the prediction of sand is based on acoustic travel time and density and its values fell between $1.98\times10^6psi^2$ and $2.89\times10^6psi^2$ with a gross average of $2.3\times10^6psi^2$. From the analysis it shows that reservoir 1-3 is greater than $2.608\times10^6psi^2$, indicating that for optimum production from this reservoir, a sand control plan is required.

4.9 Critical drawdown pressure in the Apogee field

The Critical drawdown pressure (CDD) of the wells which can attenuate sand production rate was also evaluated, the values fell between 14.48 MPa and 23.56 MPa with an average of 17.1 MPa. Normally, as reservoir fluids are being produced, pressure differential and frictional drag forces are formed which has a magnitude higher than the formation compressive strength. however, if the critical flow rate of production is maintained lower than 17.1MPa then the pressure differential and frictional drag forces will not be strong enough to exceed the rock compressive strength to cause sand production. According, when the critical drawdown pressure (CDD) is two times the reservoir unconfined compressive strength (UCS) the reservoir to a great extent is kept from sand Production.

4.10 Ranking of the sand production method

The sand production prediction methods carried out in the studied reservoir shows that the Formation falls below the threshold of the cutoffs of the four sand prediction techniques using elastic parameters and physical rock properties (acoustic time and density), as shown in Table 3. The Shear modulus to Bulk compressibility ratio (G/C_b) method predicted the highest potential of sand influx into the well. This validates that the delineated sandstone is highly unconsolidated.

In this Project, four method for prediction of sand production were used, B-index, Schlumberger-index, ratio and combined method. From well logs, elastic and inelastic properties of rock formation were calculated. The relationship between unconfirmed compressive strength for rock strength and porosity of various Reservoir in the formation showed $0.96>R^2<1$. The UCS was correlated with other parameter, it also shows high value of R^2, indication a good correlation.

Estimation of geomechanical parameters from well logs, is another reliable approach and in the absence of core data, can be used to describe the formation in term of sand potential. If the right correlation or proper model is built, we can successfully achieve the ultimate deliverables (analyzing for sand production). This work involves the evaluation of geomechanical parameters (Poisson ratio, porosity, pore pressure, Shear modulus, compressibility Young modulus, Bulk modulus and unconfined compressive strength) and correlating it to the petrophysical properties in other to be able to predict sanding potential of the reservoirs. The graphs confirm a little rise of unconfined compressive strength with elastic properties with a relative drop in porosity and acoustic travel time. The study confirm that compacted sand units have higher rock strength than the high porosity unconsolidated sandstone. The strength of the Formation (USC) have a very strong relationship with the porosity ($0.98> R^2<1$) implying that sands with high porosity have has high tendency of producing sands.

Using the result from gemechanical property evaluation to predict sand production, it confirms the Schlumberger - index, B- index , Shear modulus to Bulk compressibility ratio and Combined modulus method all predict high potential sanding of the studied reservoir during production. But if the critical flow rate of the production is maintained, the pressure differential and frictional drag forces might not be strong enough to exceed the rock compressive strength and cause sand production.

Based on the observation in this study, the sand production evaluation and Geomechanical analysis results are consistent with the unconfined compressive strength (UCS) derived from well logs and the highly porous and unconsolidated sand units of the studied reservoirs. Therefore, it is concluded that Geomechanical evaluation built for other regions of the world for optimal production do not yield accurate results when used for the Niger Delta region, as heterogeneity can cause time dependent and non-time dependent anisotropies in rock strength, elastic properties and in situ stresses.

5.0 Recommendations

From the analysis which was run on both the intact and damaged rock, the following recommendations were considered.

I. The evaluation shows that sand production is high on Apogee field, the completion engineer should therefore plan for sand management and control in order to prevent or minimize sand production on the field.
II. The evaluation shows that the sand critical production pressure difference is not high during well production. Hence during development, the production pressure differential should be controlled in other to prevent sand production.
III. To determine the point of failure of various reservoir in real time, this model should be used especially during design of well completion in other to control sand production
IV. More detailed work on sand production should be carried out to cover from exploration to developmental stages of the field
V. More studies should be done on different field within the Niger Delta to validate the adoption of this model for prediction of sanding in the Niger Delta.

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