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Research Paper

The Effects of Clay Content and Porosity on Acoustic Velocity in clastic Sedimentary Formations, in parts of the Niger Delta, Nigeria.

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Abstract
The Variation of the speed of sound with depth is a function ofseveral formation parameters,including, compaction, density, porosity, confining pressure, temperature, and interstitial fluid. Different chemical and mineralogical compositions define different lithologies of the earth formations.Velocity variations are known to correlate well with the lithological character of earthen materials, thus providing important structural and lithological information. As pore-filling materials, clay minerals block the hydraulic paths and greatly reduce the permeability and porosity of earth formations, however, they do not substantially affect the seismic wave propagation; on the other hand, when clay minerals coat the pores of rocks, they considerably alter the seismic properties of the formations, without much effect on the porosity. This study investigates the effects of clay content on the porosity and acoustic velocities of clastic sedimentary formations in parts of the Niger Delta, Nigeria.To attain the aim of this study, two composite well-logs from two wells (JIK 1, and JIK 2) in the South-South(SS) of the Niger Delta were used; from these wells the well parameters were estimated via empirical relations.
Based on the estimated well formation parameters, theacoustic velocity with the influence of clay content was evaluated following after the Han et al., (1986) model.The results indicate that, an inverse relationship exists between porosity and velocity, such that an increase in velocity results in a decrease in porosity. it is evident that the linearity of porosity to velocity is more with the porosity - model velocity relationship than just the porosity - velocity relationship. The model velocity was derived from lithological function especially; clay content, which is also a cementing material. Therefore, the presence of clay content in a formation or reservoir makes it possible and easier to infiltrate pore spaces, cement formation materials and reduce porosity that in turn influences more increase in velocity values.

Kewwords: *clay content, acoustic velocity, lithology, formation, clastic*

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I. Introduction

Clay is the most known name for a range of fine-grained earthen materials that become plastic when wet. Chemically, clay is a hydrous aluminum silicate. Contains small amounts of impurities such as potassium, sodium, calcium, magnesium and iron. One of the most common processes of clay formation is the chemical decomposition of feldspar. Clays are composed of interconnected silicate layers and secondary layer groups of metal atoms, oxygen, and hydroxyls combined to form a three-layer mineral, layer like vermiculite. During lithification, compacted layers of clay can be converted into slate. Shale can transform into slate under the intense heat and pressure that can build up in the layer. Clay has a major impact on porosity due to its ability to compact, swell and fill.

Since slate is the much available sedimentary rock on earth and clay minerals are a cogent component of slate, the elastic properties of clay are of paramount importance in soil science and geophysics. Several other disciplines such as materials science, life sciences, geology, and engineering also use clays in different ways. Variations in the speed of sound with depth are related to compaction, density, porosity, confining pressure, temperature, and interstitial fluid. Different lithologies exhibit different chemical and mineralogical compositions depending on the parent material and depositional environment, affecting the temperature and rate of such formation (Uko et al., 2002). Velocity variations are known to correlate well with the lithological character of earthen materials, thus providing important structural and lithological information (Polymenakos et al., 2005).

Several studies have investigated the effect of clay content on sound velocities in sand-clay mixtures. Velocity is not primarily affected by the formation of homogeneous sand as such, to accurately determine velocity in such a mixture, a derived relationship between velocity, porosity, pore geometry, and sand content is used. clay. Velocities are found to be more sensitive to changes in porosity than to changes in clay content; but the effect of clay in reducing formation porosity and permeability cannot be overstated. (Tosaya and Nur, 1982; Han et al., 1986; King et al., 1988). Porosity can be a remnant of sedimentation (primary porosity, pore spaces between particles that are not fully compacted) or can be caused by rock disturbances (secondary porosity). Porosity due to fractures, faults, or dissolution of feldspar grains or fossils). Total porosity is the sum of all voids in the rock, whether or not they contribute to fluid flow. Effective porosity is usually less than total porosity. Shale gas reservoirs tend to have relatively high porosity, but due to the alignment of layered particles such as clay, the permeability is very low with high sound velocities.

The speed at which sound waves travel through a medium is actually a function of the properties of the medium. Velocity can be determined from laboratory measurements, acoustic beams, and vertical seismic profiles, or from velocity analysis of seismic data. It can vary vertically, laterally, and azimuthally in anisotropic environments and tends to increase with depth. Speed also varies based on how the data is derived; for example, the velocity of stacking derived from normal measurements of motion of common-depth accumulations differs from the average velocity measured vertically from a vertical seismic profile (VSP) or test. The speed would be the same only in a homogeneous isotropic medium.

Clay 5minerals are hydrated aluminum silicates and are classified as phyllosilicates or layered silicates. All layer silicates are built from two modular units: tetrahedral and octahedral, sheets. The tetrahedron consists of oneSi_4^+ atom surrounded by four O_2^-atoms. The octahedron consists of a central Al_3^+ or Mg_2^+atom surrounded by six O_2^-atoms. The tetrahedron or octahedron is bonded by shared oxygen atoms to form the sheets. Octahedral sheets can be betioctahedral (similar to brucites) or dioctahedral (similar to gibbsites). In brucite-like sheets, the cation to anion ratio is 1:2, so the three octahedral sites around each hydroxyl must be filled to maintain electroneutrality. In gibbsite-like sheets, on the other hand, the ratio of cations to anions is 1:3, so only two of the three octahedral sites around each hydroxyl need to be filled to obtain electroneutrality.

1.1 Study Area

The study was carried out with data obtained from parts of the Niger Delta Nigeria.

General Geology of the Niger Delta

The Niger Delta is a low-gradient delta plain, shelf-slope wedge. Estimated area is 200,000km^2 and age ranges from Eocene to Recent (0–45 Ma). Features include a southward tapering profile of a low-angle depositional ramp, Taper shape- high sedimentation rates across a mud-rich slope. Structural styles include extensional expanders on the shelf and a deep water thrust and fold belt at the toe of slope. The sedimentary fill in the Niger Delta Basin is conveniently 'divided into three formations each of which is diachronous. The formations are:

Benin Formation

The Benin Formation, Fig. 1.2, is the depositional environment of the upper alluvial coastal plain of the Niger Delta Complex. It extends from the western Niger Delta through the entire Niger Delta area and southward beyond what is now the coast. A continental fluvial environment was where the formation was deposited in and consists almost entirely of non-marine sandstones. It is made up of coarse-grained sandstones, strands of grainy lignite and fragments of wood with small slate inclusions. Dating from the Miocene to younger times, the Benin Formation varies in thickness up to over 1820 m. Underground it is Oligocene in the north and progressively younger in the south, but is from the Miocene to the modern age, as is generally accepted. Very little hydrocarbon enrichment has been associated with this formation (Short and Stauble, 1967).

1.8.2. Agbada Formation

The Agbada Formation, Fig. 1.2, underpins the Benin Formation. It was established in paralic brackish to marine coastal fluvial vicinity. It consists mainly of varying sandstone, silt and shale. The sandstones are weakly sorted, rounded to partially circular, slightly solidified, but most are unsolidified. In the lower part of the formation, the sandstones transition into shale. The time period of the Agbada Formation spans from the Eocene in the north to the Pliocene in the south. It is known that the sandy parts of the formation represent the major hydrocarbon reservoirs of the Delta oil fields and the shale layers form the cap of the reservoirs. The thickness of the formation reaches a maximum of about 4500 m (Short and Stauble, 1967).

1.8.3. Akata Formation:

The Akata Formation, Fig. 1.2, it is the minimal unit in the Niger Delta complex. It comprises mainly of shales with locally interbedded sandstones and siltstones. Over time with depth, the Formation becomes darker. It was deposited in a marine environment and has a thickness that can reach 7000 m in the central part of the delta. The Akata Formation crops out offshore in diapirs along the continental slope and onshore in the northeast, where it is called the Imo Shale. According to (Short and Stable, 1967), the age of the Akata Formation ranges from the Eocene to the Recent.

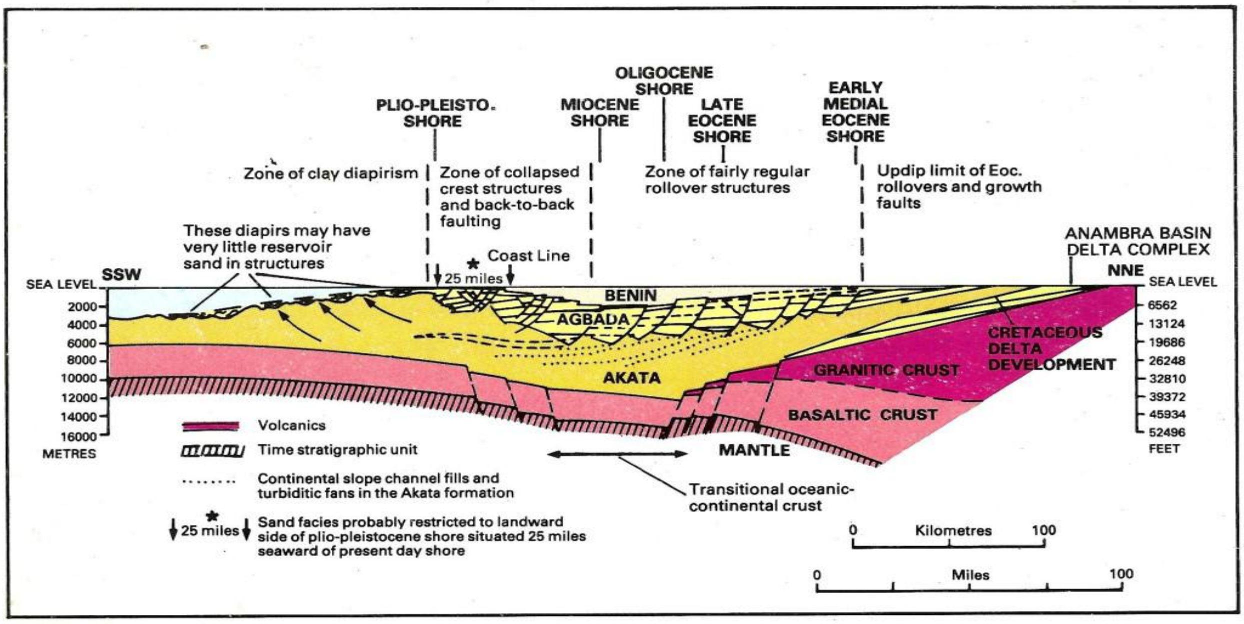

Fig. 1.2: Structural section of the Niger Delta Complex showing the formations (Short and Stauble, 1967)

II. Background theory

Some researchers differentiate lithologies based on geological time period. However, in this study, lithology is considered in terms of what it is made up of and the size of the particle. Different lithologies have distinguishing mineralogical compositions and particle sizes, depending on the parent material and depositional environment, which affect the conductivity, density, temperature, and velocity of such formations (Plummer and McGeary, 1993; Uko et al., 2002; Uko et al., 2014).

To identify lithological boundaries, bedrock topography and faults including structural heights and buried channels, vertical profiling can be used; it can also be used to predict hyperbaric zones and reservoirs. Velocity variations are known to correlate well with the lithological character of formation materials, providing important structural, lithological and dynamic soil and rock property information for seismic analysis of structures (Bosch et al., 2002; Polymenakos et al., 2005).

It has also long been known that the destructive effect of ground tremors in earthquakes can be greatly amplified by local soil situations, a term that points to the unsophisticated properties of geological formations at the surface. Therefore, the dissimilarity in seismic intensity, attenuation, and structural destruction observed in previous earthquake events has often been attributed to the variability in the lithological stratigraphy and the depth of the epicenter of a given area. In many cases, lithological properties have had a significant impact on the amplitude level, frequency composition, and duration of the ground tremor of a seismic wave. Therefore, the detailed description of the local geological conditions at each site is crucial for seismic risk assessment for microzonation studies, as well as for seismic planning and retrofitting of large-scale facilities and long structures. Telford et al., (1976) clearly stated that, clay formations are more conductive than sandy formations; which is seriously associated with the mineral contents of these different lithologies.

3.1 Materials and Methods

3.2 Nature and Sources of Data Sets

Two composite well logs (Fig. 1.1) were used for this study. These data were collected from one of the multinational oil servicing company in the South-South-West (SSW) of the Niger Delta. For confidentiality purpose of the data set, including the protection of the business interest of the company the true names of the wells were substituted to be (JIK 1, and JIK 2).

3.2.1 Well Log Data

The composite well log data used include the coordinates, tops, base map and deviation surveys. The study area was penetrated by four wireline logs. The logs available include gamma ray log (GR in API unit), resistivity log (RT in Ohm-m), Caliper log (CAL in inches), density log (DEN in g/cm^3), neutron log (NEU in m^3/m^3) and sonic log (DT in µs/ft). Other well information includes well tops, rig floor elevation, fluid fill, lithology etc. The well logs were provided in ASCII digital format.

3.3 Determination of Sand to Shale ratio

In order to determine the sand-shale relationship in the subsurface geology of the study area, the gamma ray logs for the various drill holes were divided into sections containing two lithosurfaces, namely; sandstone and slate.

The gamma ray record reflects the shale content of sedimentary formations. Clean sandstones and carbonates tend to have low natural radioactivity, while clay minerals and liquid shale particles have higher radioactivity due to adsorption of heavy radioactive elements (Schlumberger, 1987).

In general, the gamma-ray trace is useful for locating shale and non-shale layers, and particularly for popularized correlation (Schlumberger, 1987).

Clean sandstones with increasing log signatures tend towards the sandline and have low API units ranging from 0 to 30 API units. Increased energy and coarseness were identified as regressive marine environments, with higher energy at the top of the sequence. In sandy shale it is between '30 and 80 API units. Although the shales have API unit values of 80 and above, the log signatures are moving towards the shale line, showing a decrease in sedimentation rate and an overall decrease in energy; identified as flow environments and transgression sequences. The amount of each rock formation is then estimated by counting the interval of a particular rock formation and then allocating a fraction of that to the total interval within the sand-shale lines, which is then expressed as a percentage (kearey et al., 2002).

3.4 Determination of Porosity

In the Niger Delta, formation materials are mostly unconsolidated because the Niger Delta is a geologically younger formation, so using the time average Equation at some points produces spurious high porosity values than the true porosity which requires corrections (Schlumberger, 1987). To eliminate the need for the correction factor and yield porosity directly, an empirical transform equation is used. It is given as

$$\phi = C\left[\frac{\Delta t - \Delta t_{ma}}{\Delta t}\right] x100 \quad (3.1)$$

where Δt = Transit time from the log, and Δt_{ma} = Transit time of matrix

Where C is the correction factor given as 0.67.

Therefore, porosity is the fractional volume of the pore space of the total rock volume expressed as a percentage. It can be assumed that all grains in the matrix have the same physical features. The major rock-forming minerals, quartz, clay mineral, feldspar, and calcite, have quite similar physical characteristics. In this case, the bulk rock properties will be an average of the properties of the matrix minerals and the pore fluid, weighted according to the density of a rock, where the bulk density p_b can be related to the matrix (p_m) and pore fluid densities.

(p_f): $$\phi = \frac{\rho_m - \rho_b}{\rho_m - \rho_f} \quad (3.2)$$

Where ϕ = porosity ρ_m

3.5 Determination of Density

The density of a matrix was obtained by digitizing Bulk Density Log.

3.6 Determination of Resistivity

The resistivity of formation materials at chosen depths was delineated from the resistivity logs

3.7 Determination of Acoustic Velocity

This is reliant on the basis that sonic travel time is directly related to sonic velocity, which is a function of formation lithology and porosity. The sound log is simply a record of the time it takes for a sound wave to traverse one foot of the formation, called the interval travel time (Schlumberger, 1987).

Sonic log is also a measure of a formation's ability to transmit sound waves. Geologically, this capacity varies with lithology and rock texture, particularly porosity when the lithology is known. This makes the sound log very useful as a porosity log. Integrated sound propagation times are also helpful when interpreting seismic recordings. The time-of-flight values were determined

using the simple ratio method. The travel time of the sonic log interval is represented by a solid line increasing from right to left on a scale of 40 – 240 μs/ft (Figs. 3.1 and 3.2).

Interval transit times were digitized with respect to the chosen depth of 25m interval. The range has 10 evenly distributed vertical divisions, which means that one division is 20 μs/ft. The compressional velocity (Vp) parameters with the influence of clay content was determined using Han et al., (1986) models as stated below after the computation of the porosity values of the formations.

$$V_p = 5.59 - 6.93\phi - 2.18\,C \qquad (3.3)$$

Where Vp is in Km, ϕ is the porosity, and C is the clay content, which represents the shale percentage

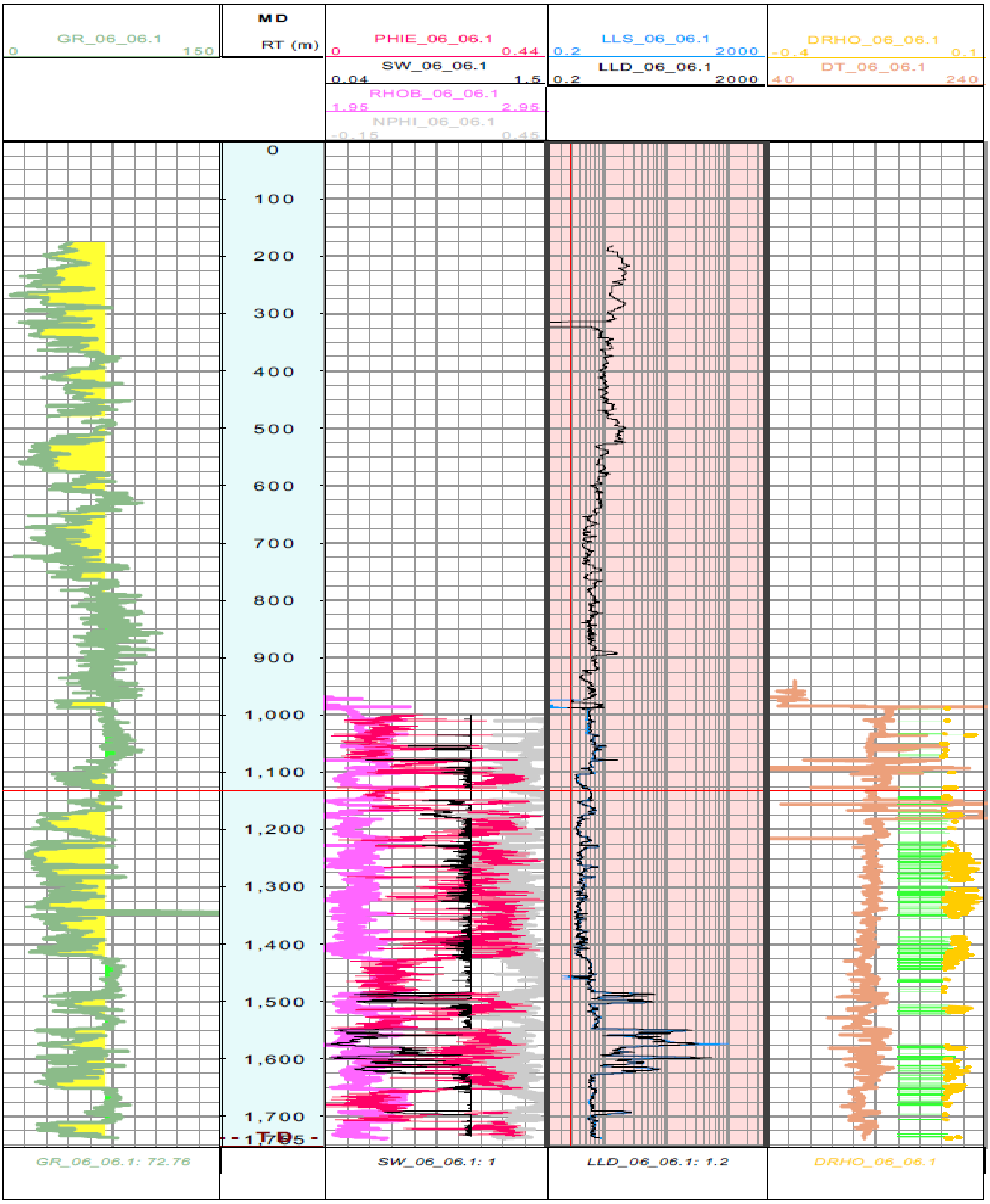

Fig. 3.1: Composite Well-Log for Well JIK 1

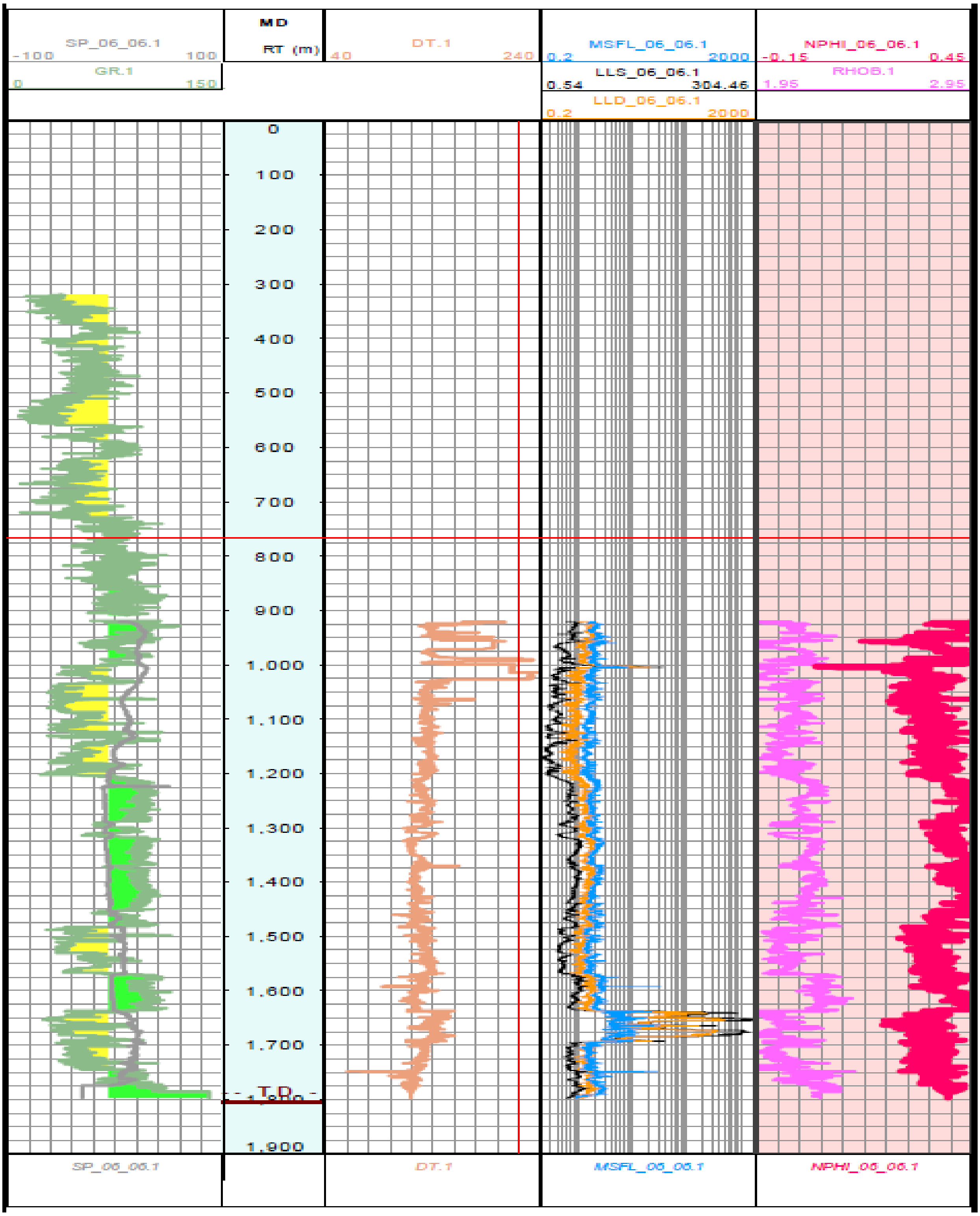

Fig. 3.2: Composite Well-Log for Well JIK 2

4.1 RESULTS and Discussions

4.1.1 Lithologic Depth columns delineated

The lithologicformations delineated from the logs, for Well JIK 1, corresponding to the loggeddepths are presented in columns three and four of Table 3. Whereas, the lithologies delineated from the logs, for Well JIK 2, corresponding to the logged depths, are presented in columns three and four of Table 4.

Table 3: Computed values for Shale/Sand ratio, Transit Times, Compressional Velocities, Densities, Porosities and Model Velocities with Clay for Well JIK 1

Depth(m)	GR (API)	Shale %	Sand %	Interval Transit Time (µs/ft)	Velocity (V_p)(m/s)	Density (g/cm^3)	Porosity (%)	Model Velocity with Clay content ($V_{p,c}$) (m/s)
1000	78	52	48	156	1954	2.10	33.33	2146
1025	82	55	45	146	2088	2.13	31.52	2214
1050	85	57	43	138	2209	2.24	24.85	2633
1075	82	55	45	170	1793	2.24	24.85	2676
1100	78	52	48	182	1675	2.29	21.82	2944
1125	76	51	49	160	1906	2.38	16.36	3352
1150	78	52	48	218	1398	2.23	25.46	2692
1175	40	27	73	236	1291	2.01	38.79	2321
1200	53	35	65	146	2088	2.08	34.55	2426
1225	20	13	87	145	2103	2.20	27.27	3409
1250	30	20	80	140	2178	2.22	26.06	3348
1275	36	24	76	142	2147	2.18	28.49	3093
1300	65	43	57	140	2178	2.23	25.46	2881
1325	47	31	69	136	2242	2.15	30.30	2807
1350	54	36	64	136	2242	2.15	30.30	2705
1375	63	42	58	138	2209	2.13	31.52	2490
1400	67	45	55	138	2209	2.23	25.46	2852
1425	82	55	45	132	2310	2.22	26.06	2592
1450	83	55	45	135	2258	2.31	20.61	2956
1475	82	55	45	136	2242	2.30	21.21	2928
1500	34	23	77	150	2033	2.10	33.33	2786
1525	75	50	50	130	2345	2.37	16.97	3324
1550	76	51	49	155	1967	2.13	31.52	2302
1575	40	27	73	147	2074	2.10	33.33	2699
1600	70	47	53	146	2088	2.23	25.46	2809
1625	68	45	55	147	2074	2.22	26.06	2796
1650	73	49	51	140	2178	2.17	29.09	2513
1675	80	53	47	132	2310	2.32	20.00	3041
1700	82	55	45	128	2382	2.25	24.24	2718
1725	47	31	69	135	2258	2.15	30.30	2807

Table 4: Computed values for Shale/Sand ratio, Transit Times, Compressional Velocities, Densities, Porosities and Model Velocities with Clay for Well JIK 2

Depth (m)	GR (API)	Shale%	Sand%	Interval Transit time (µs/ft)	Velocity (V_p)(m/s)	Density (g/cm^3)	Porosity (%)	Model Velocity with Clay content (m/s)
925	106	71	29	184	1656	2.19	27.88	2118
950	105	70	30	195	1564	2.29	21.82	2552
975	98	65	35	138	2209	2.20	27.27	2276
1000	101	67	33	218	1399	2.18	28.49	2148
1025	70	47	53	160	1906	2.08	34.55	2179

1050	43	29	71	137	2225	2.15	30.30	2865
1075	45	30	70	138	2209	2.12	32.12	2710
1100	66	44	56	140	2178	2.17	29.09	2615
1125	108	72	28	147	2074	2.21	26.67	2172
1150	52	35	65	130	2345	2.13	31.52	2650
1175	50	33	67	131	2327	2.01	38.79	2175
1200	47	31	69	120	2540	2.13	31.52	2723
1225	102	68	32	132	2310	2.28	22.42	2554
1250	103	69	31	142	2147	2.29	21.82	2581
1275	97	65	35	120	2541	2.15	30.30	2080
1300	88	59	41	110	2772	2.16	29.70	2253
1325	103	69	31	112	2722	2.28	22.42	2539
1350	100	67	33	126	2420	2.22	26.06	2331
1375	98	65	35	120	2541	2.24	24.85	2444
1400	97	65	35	118	2584	2.25	24.24	2500
1425	107	71	29	130	2345	2.22	26.06	2229
1450	102	68	32	128	2382	2.08	34.55	1714
1475	105	70	30	130	2345	2.10	33.33	1754
1500	115	77	23	137	2225	2.20	27.27	2029
1525	35	23	77	140	2178	2.02	38.18	2435
1550	73	49	51	142	2147	2.05	36.36	2009
1575	108	72	28	108	2823	2.33	19.39	2676
1600	115	77	23	146	2088	2.29	21.82	2407
1625	98	65	35	126	2420	2.32	20.00	2780
1650	27	18	82	157	1942	2.18	28.49	3224
1675	45	30	70	145	2103	2.05	36.36	2416
1700	82	55	45	121	2520	2.20	27.27	2508
1725	68	45	55	134	2275	2.13	31.52	2418
1750	92	61	39	126	2420	2.30	21.21	2783
1775	108	72	28	130	2345	2.33	19.39	2676
1800	141	94	6	120	2541	2.23	25.46	1777

Tables 3 and 4, show that, wells JIK 1 and 2, were logged for a set of 1000 – 1725 km and 925 – 1800 km respectively. The lithologies delineated were Shale and Sands, as expressive of theNiger Delta basin. The shale percentage for Well JIK 1 varied from a minimum of 13 at a depth of 1225km to a maximum of 57% at a depth of 1050 km. while the sand percentage ranges from 43 – 87%, for depths of 1050km and 1226 km. this indicates that the sand-shale percentages reciprocate each other.

4.1.2 Estimated Density, Porosity and log obtained acoustic Velocity

The densities and porosities, estimated for Well JIK 1, as shown in Table3, ranges from 2.01 to 2.38g/cm^3, (at corresponding depths of 1175 and 1135 km), and16.36 –38.79% (at depths of 1127 and 1175 km) respectively. Similarly, The densities and porosities, estimated for Well JIK 2, as shown in Table 4, ranges from 2.02 to 2.33 g/cm^3, (at corresponding depths of 1575 and 1775 km), and 21.21 – 30.30 % (at depths of 1750 and 1275 km) respectively.

4.2Cross correlation of various computed parameters

4.2.1 porosity profile

The porosity (profile) plotted against depth for both Wells JIK 1 & 2 are presented in Figs..3 and 4.The trend shows porosity decrease with increase in depth. This decrease in porosity with depth was not also very linear; from the Figures, the porosity of deeper layers shows significantly lower values than overlain layers, this probably may be due to poor compaction and unconsolidatedunderlying young layers, and also as a resultof sorting of the formation materials at depositional stage.

The porosity of a bulk formation layer is well associated with the type of the clastic materials, the overburden pressure, the hydrostatic pressure and the composition of the material.

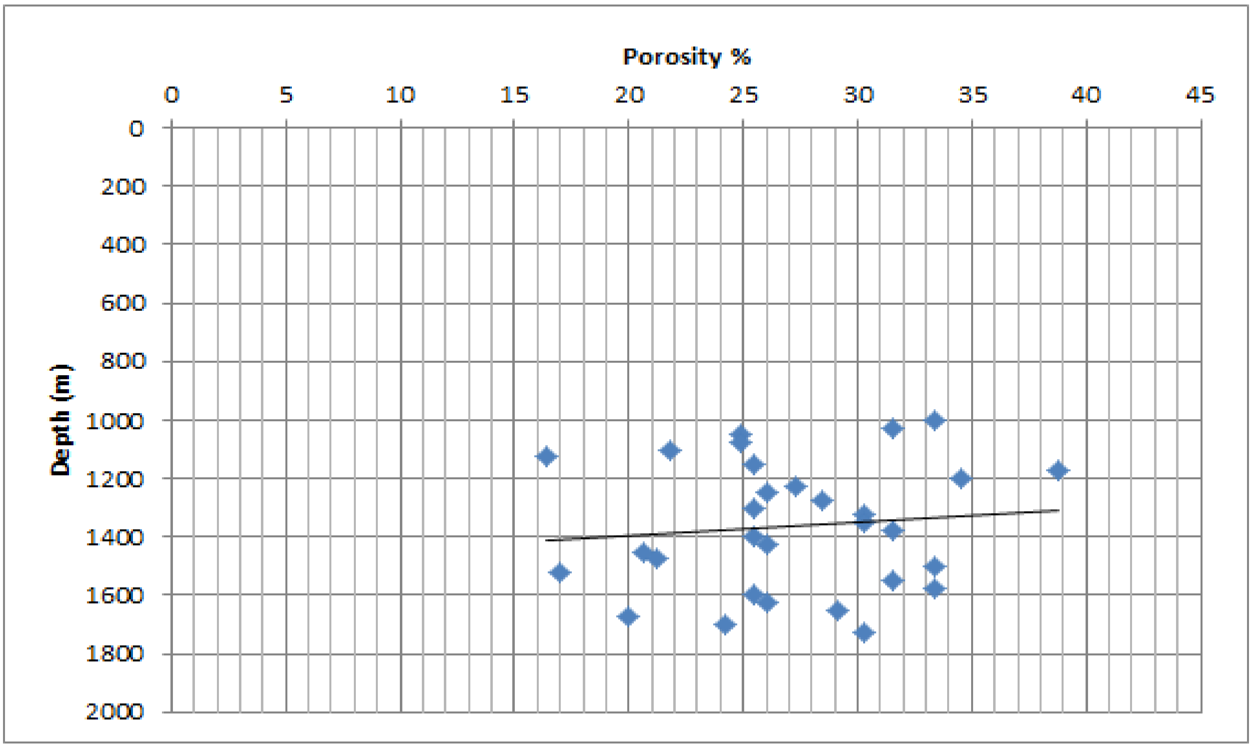

Fig.3: Porosity against depth for Well JIK 1

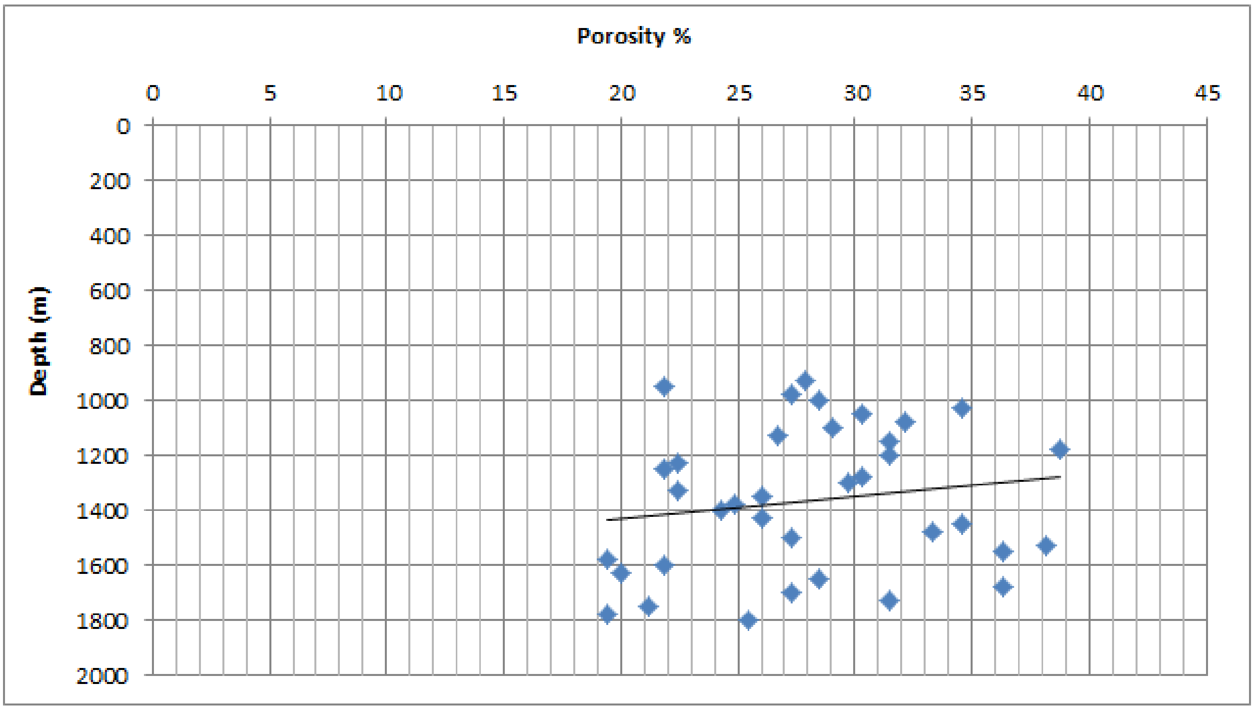

Fig. 4: Porosity against Depth for Well JIK 2

4.2.2 cross correlation of porosity with velocity

The cross correlation of porosity with the log obtained velocity, for Well JIK 1, is presented in Fig.5; while the correlation of porosity with modeled velocity is presented in Fig.6.. The cross correlation of porosity and the log obtained velocity, for Well JIK 2, is presented in Fig.7, while the correlation of porosity with modeled velocity for Well JIK 2. is presented in Fig. 8.

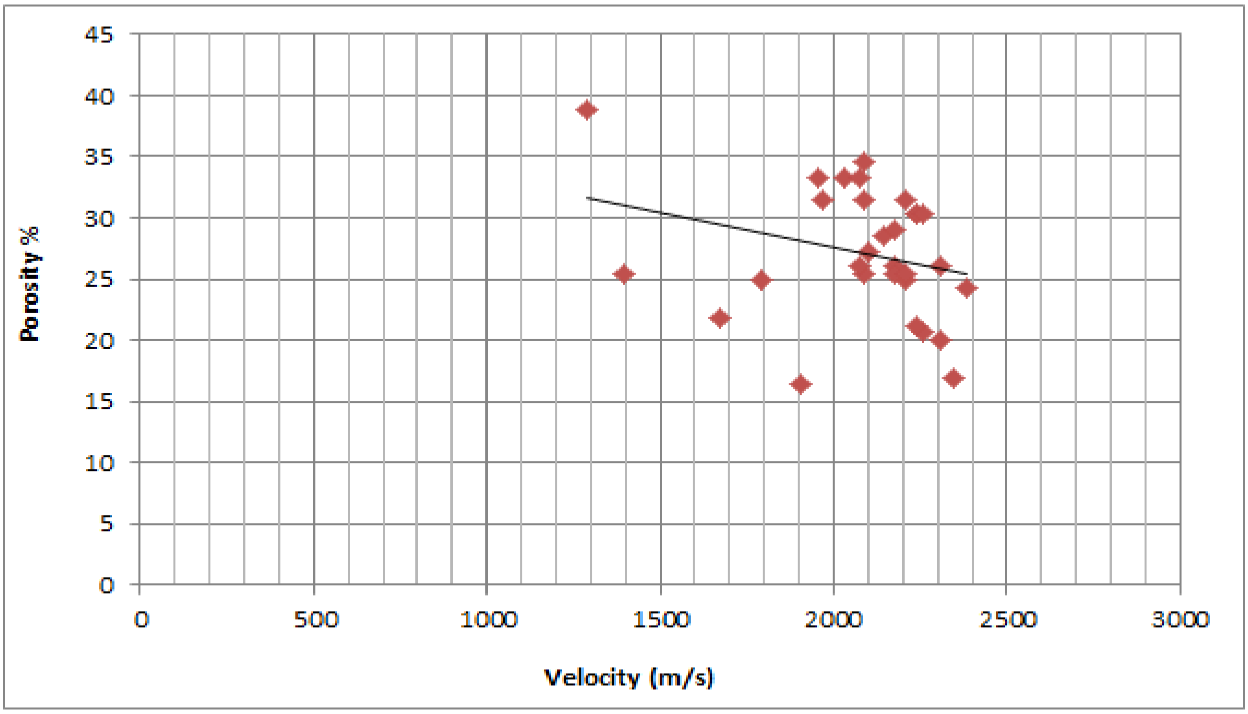

Fig.5: Porosity against log Velocity for Well JIK 1

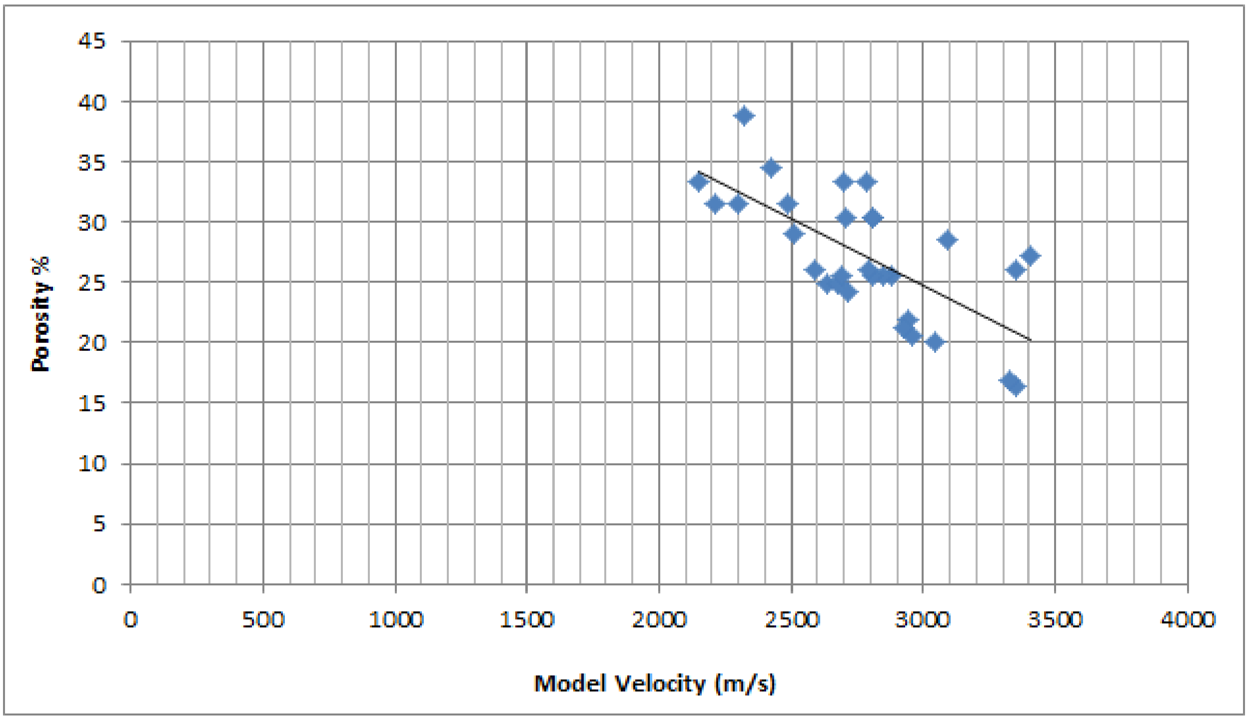

Fig. 6: Porosity against Model Velocity for Well JIK 1

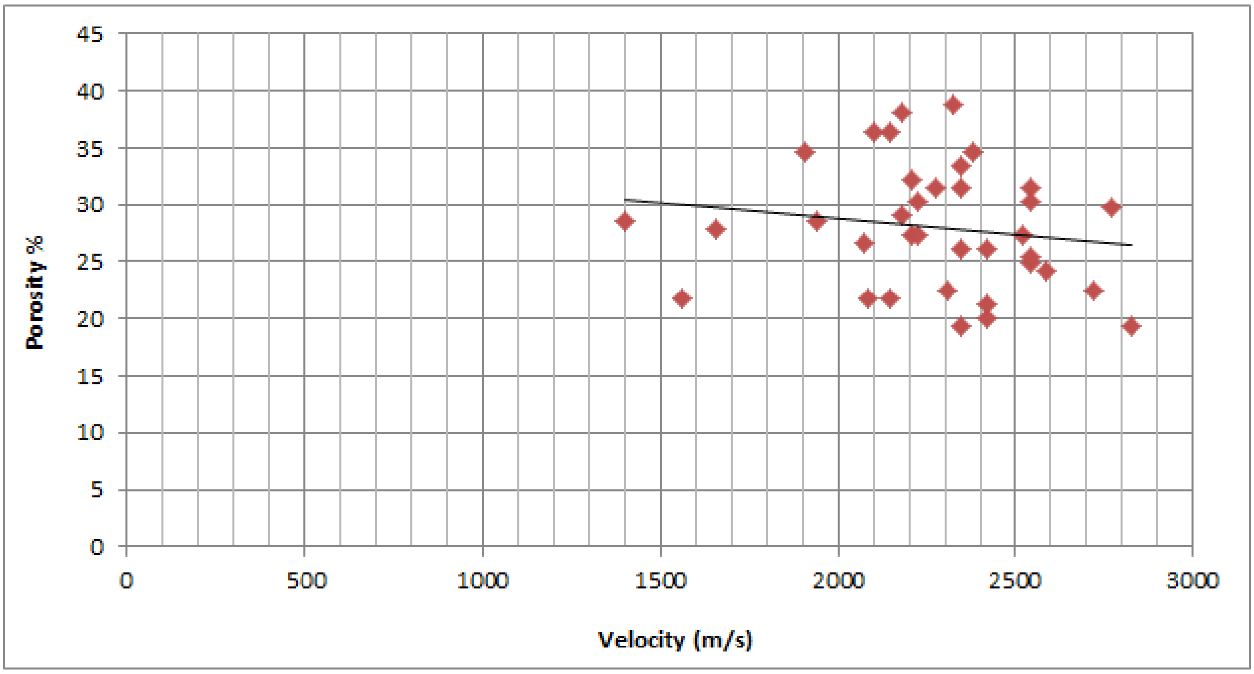

Fig. 7: Graph of Porosity against Velocity for Well JIK 2

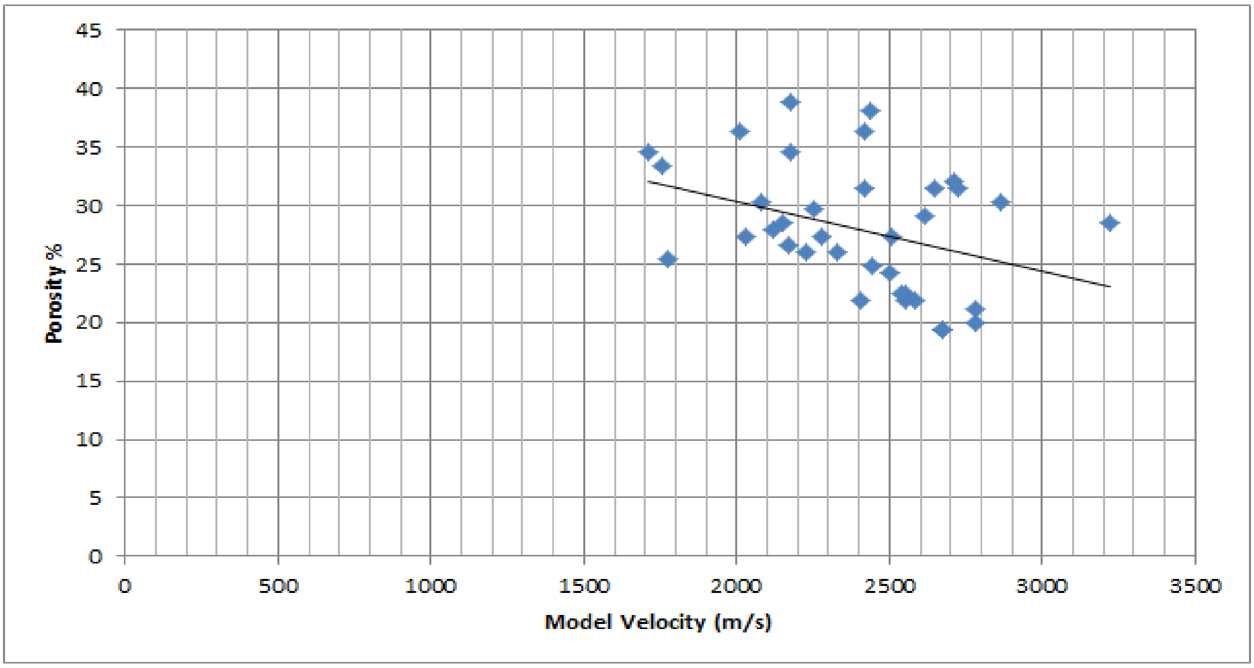

Fig. 8: Graph of Porosity against Model Velocity for Well JIK 2

Figs. 5 to 8, shows the relationship between porosity and velocity (both log computed and modeled).The Figs indicate an inverse relationship between the two parameters; increasing velocity as porosity decreases. It is evident that the linearity of porosity to velocity is more with the porosity - model velocity relationship than in the porosity - velocity relationship. Since the model velocity was derived from clay content, which is a cementing material, and considering the fact that, thepresence of clay content in a formation or reservoir, makes it possible and easier pore spaces for be filled up, and hence reduce the porosity of the formation, thereby increasing the velocity values.

4.2.3 Correlation of density with velocity

The cross correlation of density with log obtained velocity for Well JIK 1, is presented in Fig.9, while the plot of density against modeled velocity for Well JIK 1, is presented in Fig.10.The plots of density against log obtained velocities and modeled velocities for Well JIK 2, are show in Figs. 11 and 12 respectively..

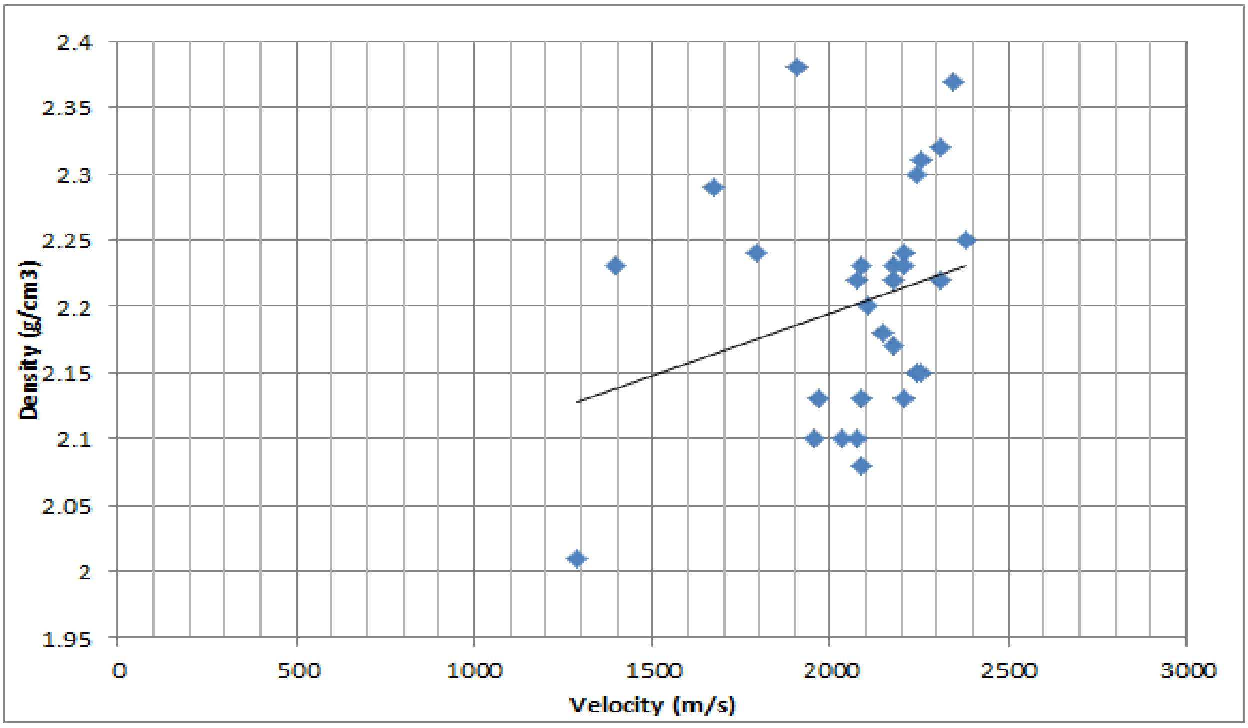

Fig.9: Density against Velocity for Well JIK 1

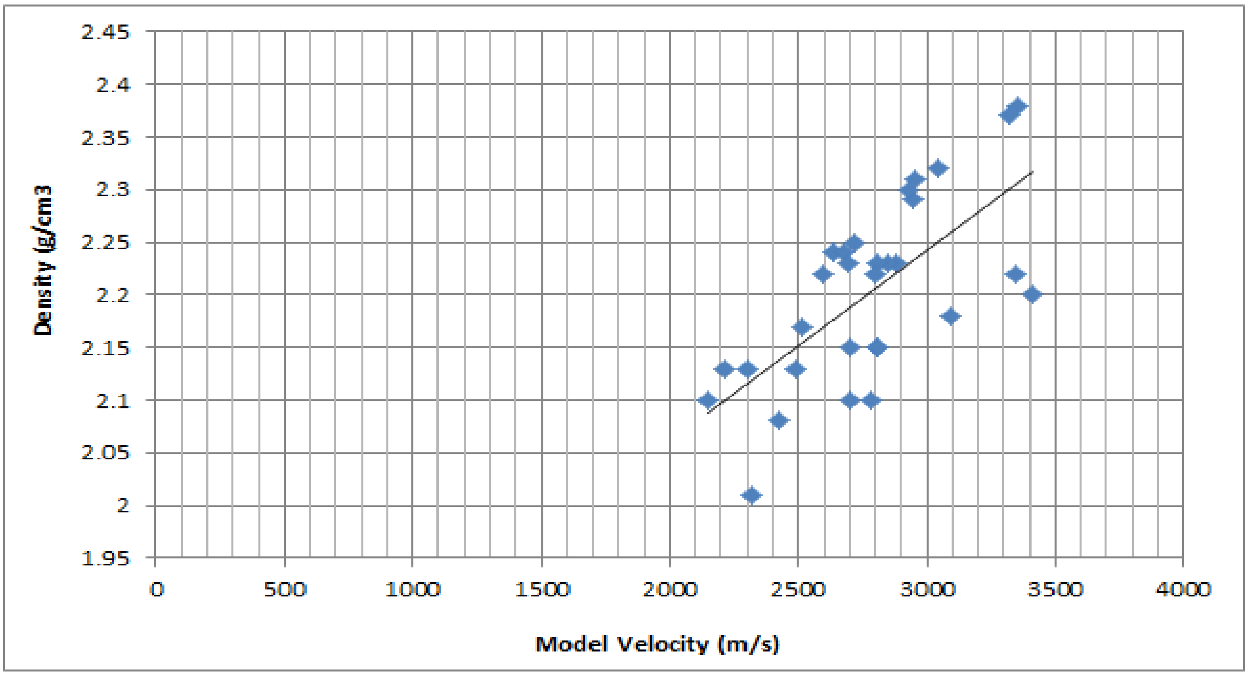

Fig.10: Graph of Density against Model Velocity for Well JIK 1

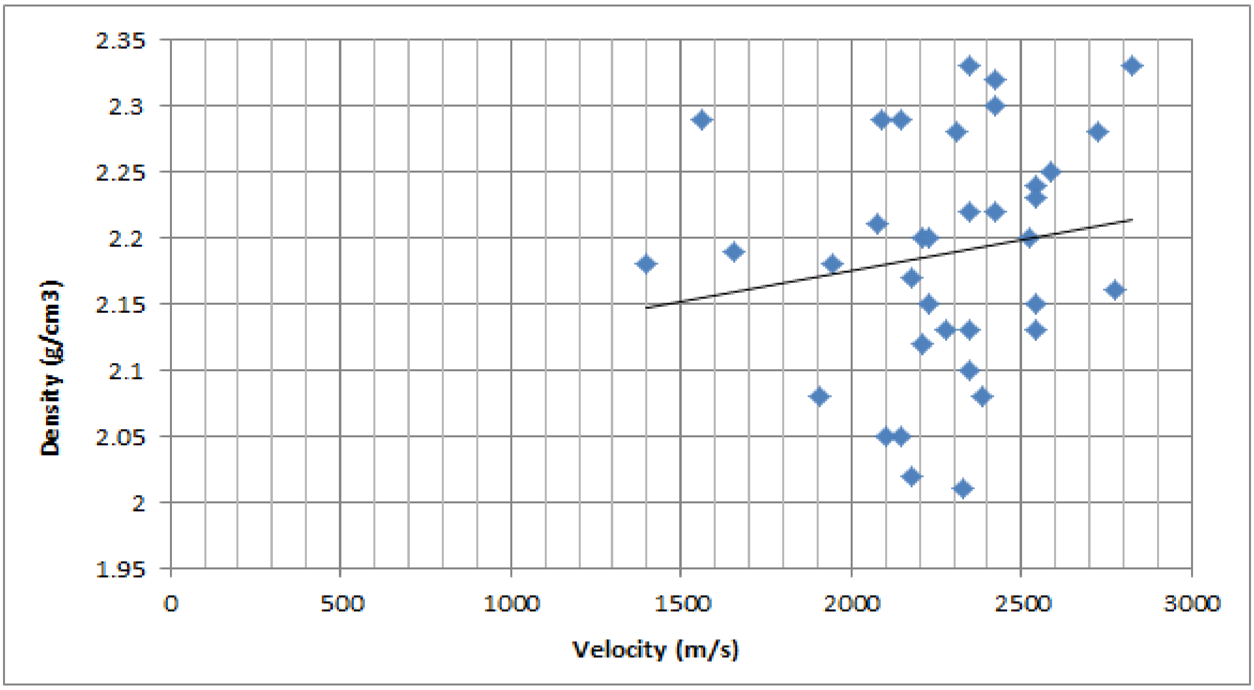

Fig.11: Density against Velocity for Well JIK 2

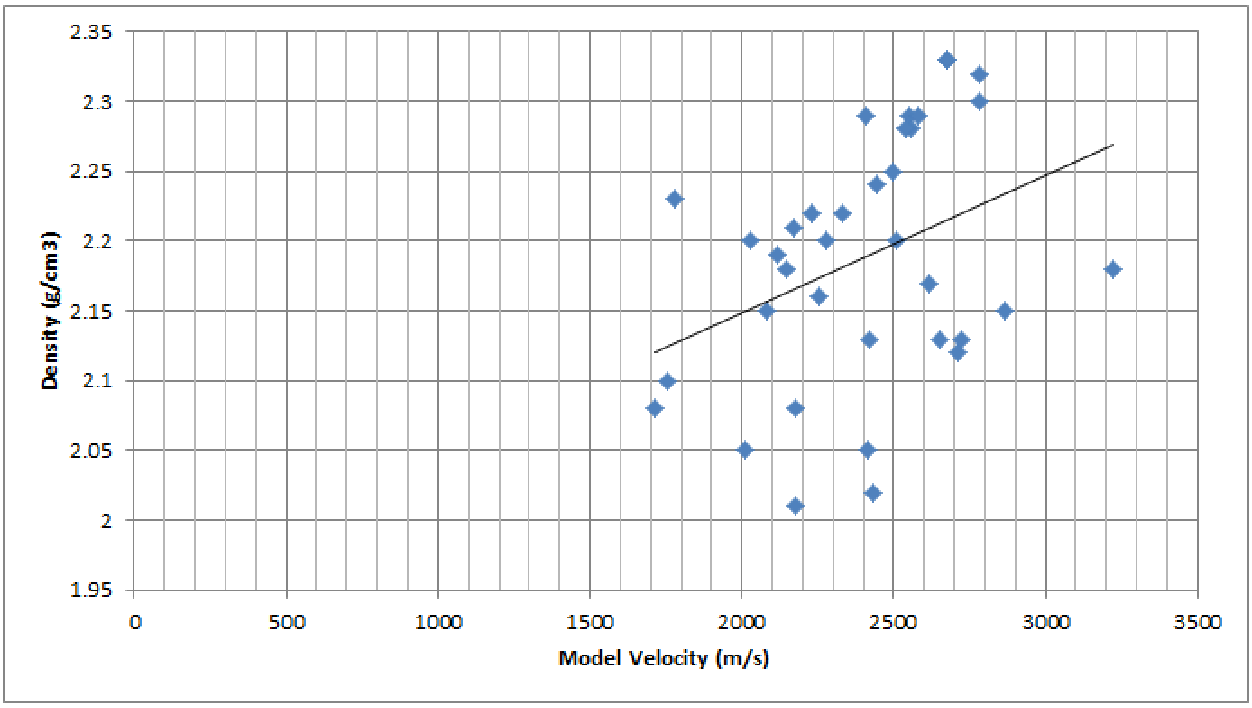

Fig.12: Density against Model Velocity for Well JIK 2

4.5 Computed and Modeled compressional velocity

The log computed acoustic velocity, from transit time, for wells JIK 1 and 2, as presented in columns 6-8, of Tables 3 and 4, show that the log computed acrostic velocities range from 1291 – 2382km/hr and 1399 – 2551km/hr respectively, while the modeled velocities ranged from 2146 – 3348 km/hr, and 1718 – 2865km:hr, for the respective wells.

A cross plot of the modeled and computed velocities for Wells JIK 1 and 2, are shown in Figs. 13 and 14, respectively.The relationship between the velocity parameter and the model velocity as shown in Figs.13 and 14, was evident that the modeled velocity valueswere higher than the log obtained velocity values (computed from the interval travel times, digitized from the well-logs). This is probably because of the derivation of the model velocity from porosity and clay content; the higher valuesof the model velocities are basically a function of the large surface area of clay contents and its ability to infiltrate pores to reduce porosities of such areas and strata to cause high velocity of seismic signals or waves as they traverse through such formations.

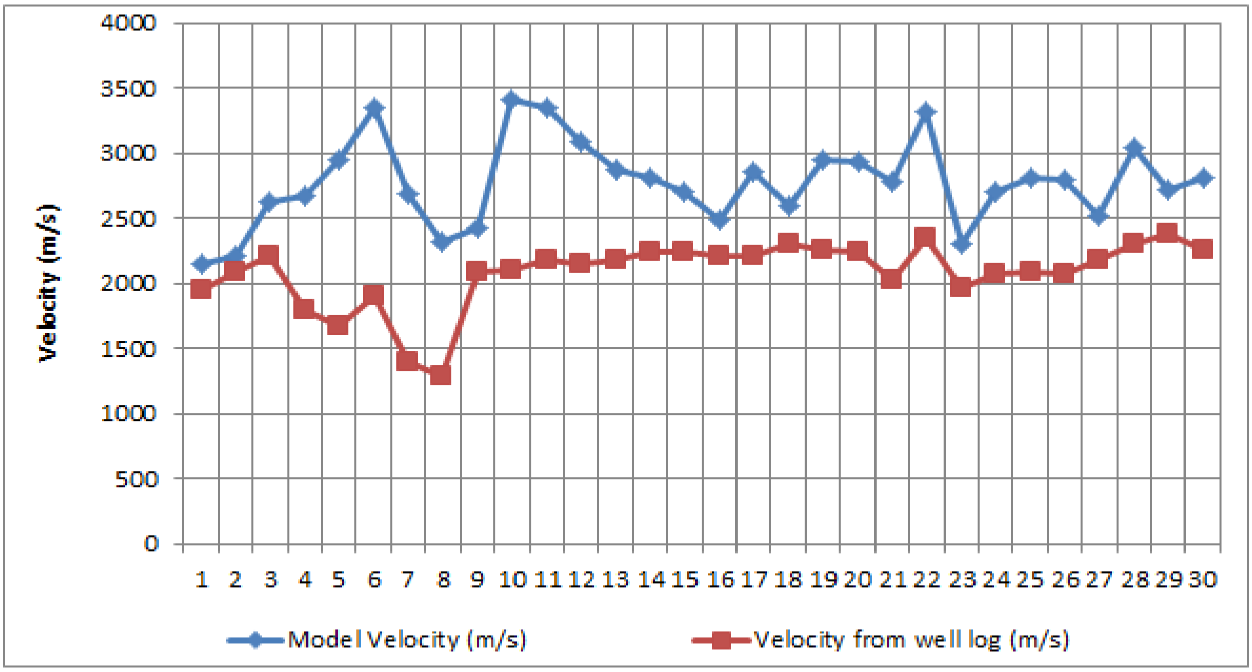

Fig. 13: A Plot of the Velocity from the Log and the Model Velocity for Well JIK 1

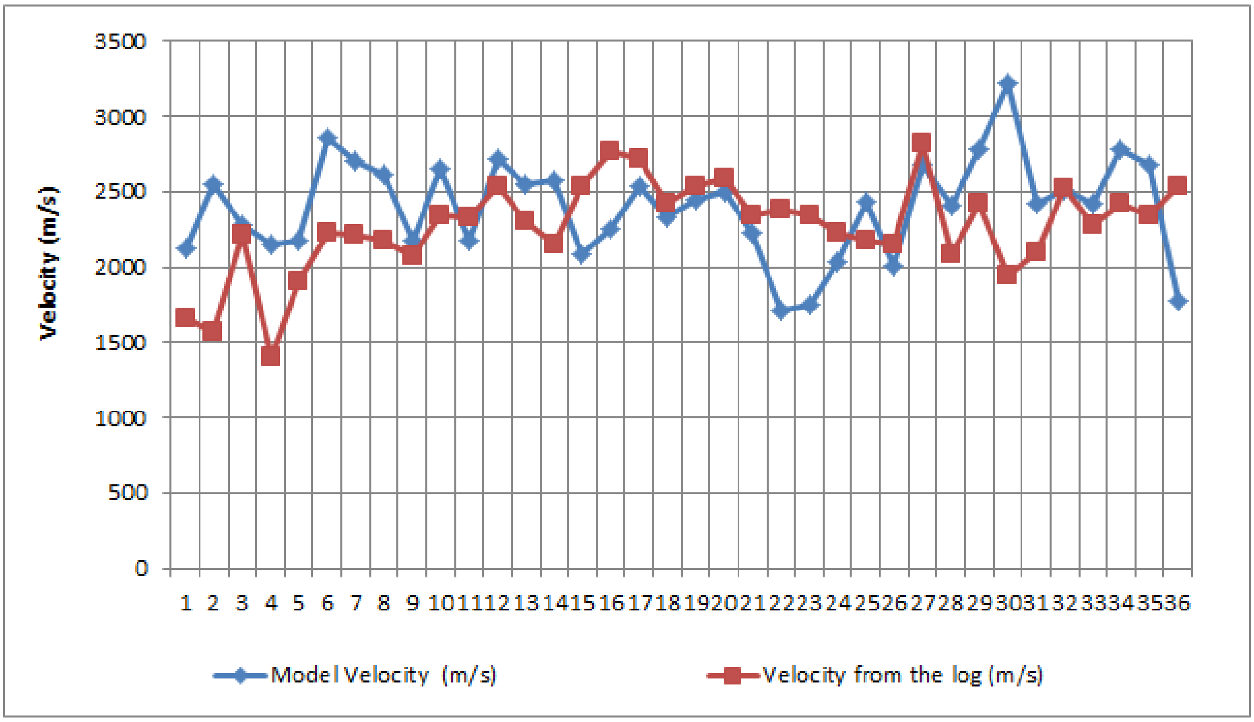

Fig.14: A Plot of the Velocity from the Log and the Model Velocity for Well JIK 2

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V. Conclusions

This study has investigated the effects of clay content and porosity on the compressional velocity of lithologic formations. It has been shown that, reductionin the porosity of clastic sedimentary layers, is attributed to the presence of clay content.Clay minerals are infilling in clastic sedimentary formations and contribute in the reduction of formation porosity, which in turn influences acoustic velocities.Clay mineral by their swelling characteristics can seal migratory paths of fluids through faulted formations during production process.

In refraction survey for both water and hydrocarbon exploration; the presence of clay minerals can influence acoustic velocity and the first arrival times of signals.

During production and abstraction stages of fluid, the presence of clay minerals can reduce formation porosity and permeability; thereby affect formation hydrostatic pressure and reduce yield of fluid to boreholes and wells.

Recommendations

Findings from the results and conclusions so drawn, the following recommendations are highlighted:

The impact of clay minerals in the yield strength determination of a producing reservoir during 4D or Time-Lapse survey should be taken very seriously.

Consequential impact of clay mineral should be the first line of action in planning and mapping of well-bore maintenance programmes.

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Conflict of interest

The authors affirm that, in the course of execution of this study there were no conflict of interests.

References

[1]. Baver, L.D, Gardner, W.H. & Gardner, W.R (1972). Soil Physics, 4th ed, John Wiley and Sons, New York.
[2]. Beard, D. C. &Weyl, P. K. (1973). Influence of Texture on Porosity and Permeability of unconsolidated sand. AAPG. Bulletin, 57, 349 – 369.
[3]. Billault V., Beaufort D., Baronnet A. &Lacharpagne J. C. (2003) A nanopetrographic and textural study of grain-coating chlorites in sandstone reservoirs. Clay Minerals, 38, 315 - 328.
[4]. Bosch, M., Zamora, M. &Utama, W. (2002). Lithology Discrination from Physical Rock Properties, Geophysics, 67(2), 573 – 581.
[5]. Bultman, M. W. (1999). Geometry, Structure, and Concealed Lithology of the San Rafael Basin, South-Eastern Arizona
[6]. Burst, J. F. (1969). Diagenesis of Gulf Coast Clayey sediments and its possible Relation to Petroleum Migration. AAPG. Bulletin, 37 (2), 410 – 432.
[7]. Dallmus, K. F. (1958). Mechanics of Basin Evolution and Relation to the Habitat of Oil in the Basin, American Association of Petroleum" Geologists Bulletin, 36, 305 – 345.
[8]. Dickson, G. (1953). Reservoir Pressure in Gulf-West Louisiana – American Association of Petroleum Geologists Bulletin, 37 (2), 410 – 432.
[9]. Dobrin, M. B. (1981). Introduction to Geophysical Prospecting, 3rd Ed. McGraw-Hill Book Company, Singapore.
[10]. Etu-Efeotor, J. O. (1997). Fundamentals of Petroleum Geology, Paragraphics, Port Harcourt, Nigeria.
[11]. Faust, L. Y. (1951). Seismic Velocity as a function of Depth and Geologic time. Geophysics, 16, 192 - 206.
[12]. Han, D.H., Nur, A., & Morgan, D. 1986. Effects of Porosity and Clay Content on wave velocities in Sandstones. Geophysics, 51, 2093–2107.
[13]. Hillier S. (1994) Pore-lining chlorites in siliciclastic reservoir sandstones: electron microprobe, SEM and XRD data and implications for their origin. Clay Minerals, 29, 665 - 679.
[14]. Hornby, B. E. (1998). Experimental Laboratory Determination of the Dynamic Clastic Properties of Wet Drained Shales. Journal of Geophysical Research, 103, 29945 – 29964.
[15]. Hubbert, M. K. &Rubey, W. W. (1959). Role of Fluid Pressures in Mechanics of Overthrust Faulting: I. Mechanics of Fluid-Filled Porous Solids and its Application to Overthrust Faulting. Gsa Bulletin, 70, 115-116.
[16]. Ikeagwuani, F. D. (1979). Trends of Petroleum Exploration in Nigeria. The Petroleum Inspectorate, NNPC, Lagos.
[17]. Johansen, T. A., Rwud, B. O. &Jakobsen, M. (2004). Effect of Grain Scale Alignment of Seismic Anisotrophy and Reflectivity of shale, Geophysical Prospecting, 52, 133 – 149.
[18]. Jones, T. &Nur, A. (1981). Effect of temperature on velocity and attenuation of seismic waves in rocks: Applications to crustal exploration. AAPG", 65, 1361
[19]. Judson, D. R., Lin, J., Schultz, P. S., & Sherwood, J. W. C. (1980). Depth Migration after Stack; Geophysics, 45, 376 - 393.
[20]. Kearey, P., Brooks, M., & Hill, I. (2002). An Introduction to Geophysical Exploration, 3rd Ed. T. J. International, Pad Stow, Cornwell.
[21]. King, M. S., Stauffer, M.R., Yang, H. J. P., &Hajnal, Z. (1988). Elastic-wave and Related Properties of Clastic Rocks from the Athabasca Basin; Canadian Journal of Exploration Geophysics, 24, 110 - 116.
[22]. Lee, J. M., Shackelford, C. D., Benson, C. H., Jo, H. Y. &Tuncer, B. E. (2005). Correlating index properties and hydraulic conductivity of geosynthetic clay liners. Journal of Geotechnical and Geoenvironmental Engineering, 131(11), 1319-1329.
[23]. Lowrie, W. (2004). Fundamentals of Geophysics, 6th Ed., Cambridge University Press, United Kingdom, pp. 84 - 98.
[24]. Magara, K. (1968). Compaction and Migration of Fluids in Miocene Mudstone, Nagaoha plain Japan, American Association of Petroleum Geologist Bulletin, 52, 305 – 349.
[25]. Moore, Duane M., & Reynolds, JR. Robert C. 1989. X-ray Diffraction and the Identification and Analysis of Clay Minerals. Oxford, New York: Oxford University Press.
[26]. Netheton, L. L. (1976). Gravity and Magnetics in Oil Prospecting, McGraw-Hill, New York.
[27]. Ngeri, A. P., Tamunobereton-ari, I., Horsfall, O. I. (2018), Seismic Noise Attenuation from an Arctic Glacier Data, Asian Journal of Applied Science and Technology, 2(4), 212 - 220.
[28]. Ofoegbu, C. D. (1985). A Review of the Geology of the Benue Trough, Nigeria. Journal of African Earth Sciences, 3, 283 – 291.
[29]. Plummer, C. C. &McGreary, D. (1993). Physical Geology, 6th Ed. Wm. C. Brown Publishers, England
[30]. Polymenakos, L., Papamarinopoulos, S., Miltiadou, A., &Charkidakis, N. (2005). Investigation of the Foundation of a Byzantine Church by Three-Dimensional Seismic Tomography; Journal of Applied Geophysics", 57, 81 - 93.

[31]. Prasad, M. 2001. Mapping Impedance Microstructures in Rocks with Acoustic Microscopy. The Leading Edge, 20, 172–179.
[32]. Raymer, L. L., Hunt, E. R., & Gardner, J. S. (1980). An improved sonic transit time porosity transform: 21st Annual Logging Symbosium, Trans. Soc. Prof. Well log Analysis.
[33]. Reynolds, J. M. (1997). An Introduction to Applied and Environmental Geophysics, John Wiley & Sons Ltd., West Sussex, England.
[34]. Rieke, H. H. &Chiligarian, G. V. (1974). Compaction of Argillaceous sediments: Elserier, Amsterdam.
[35]. Schlumberger, (1987). Log Interpretation: Principles/Applications, Schlumberger Education Services, USA.
[36]. Selley, R. C. (1978). Concept and methods of subsurface facies Analysis. Imperial College University press, London.
[37]. Sheriff, R. E. (1991). Encydopaedic Dictionary of Exploration Geophysics, 3rd Ed. Society of Exploration Geophysicist, USA.
[38]. Short K. C. &Stauble, A., (1967). Outline of Geology of Niger Delta, America Association of Petroleum Geologists Bulletin, 51, 761 - 779.
[39]. Stesky, R. M. (1978). Rock friction-effect of confining pressure, temperature and pore pressure. Pure and Applied Geophysics, 116(4 – 5), 690 – 704.
[40]. Suman, R. & Ruth, D. (1993). Formation factor and tortuosity of homogeneous porous media: Transport in porous media, 12, 185 – 206.
[41]. Tabor, D. (1970). Gases, liquids and solids. Penguin Books Ltd., Harmondsworth, Middlesex, England, pp. 134 – 170.
[42]. Tamunobereton-ari, I., Omubo-Pepple, V.B. & Uko, E. D. (2010). The Influence of Lithology and Depth on Acoustic Velocities in South-East Niger Delta, Nigeria. American Journal of Scientific and Industrial Research, **1**(2), 279 – 292.
[43]. Telford, W. M., Sheriff, R. E., Geldart, L. P. & Keys, D. A. (1976). Applied Geophysics, 2nd Ed. Cambridge University press. London.
[44]. Tosaya, C.A. (1982). Acoustical properties of clay-bearing rocks. Ph.D. thesis, Stanford University.
[45]. Uko, E. D., Akpabio I. O. & Okon, A. A. (2002). Ground vibration effects from seismic exploration in the Niger Delta, Nigeria. Journal of Natural and Applied Sciences, 3, (1), 64 – 69.
[46]. Uko, E. D., Benjamin, F. S. & Tamunobereton-ari, I., (2014). Characteristics of soils for underground pipeline laying in the southwest Niger Delta, International Journal of Computational Engineering Research (IJCER). 4(5), 2250 – 3005.
[47]. Wang, L. Y., Cowin, S. C., Weinbaum, S. &Fritton, S. P. (2000). Modeling tracer transport in an Osteon under cyclic loading. Annals of Biomedical Engineering, 28(10), 1200 - 1209.
[48]. Wilson, M. J., Wilson, L., &Patey, I. (2014). The influence of individual clay minerals on formation damage of reservoir sandstones: A critical review with some new insights. Clay Minerals, 49(2), 147–164.
[49]. Wyllie, M., Gardner, G., & Gregory, A. (1963). Studies of elastic wave attenuation in porous media: Geophysics, 27, 569 – 589.
[50]. Wyllie, M., Gregory, A., & Gardner, G. (1958). An experimental investigation of factors affecting elastic wave velocities in porous media: Geophysics, 23, 459 – 493.
[51]. Wyllie, M., Gregory, A., and Gardner, G. (1956). Elastic wave velocities in heterogeneous and porous media: Geophysics, 21, 41 – 70.
[52]. Zhang, J., Al-Bazali, T.M., Chenevert, M.E., Sharma, M.M., Clark, D.E., Benaissa, S., &Ong, S. (2006). Compressive Strength and Acoustic Properties Changes in Shales with Exposure to Water-based Fluids. U.S. Symposium on Rock Mechanics (USRMS), 41(06900), 900–912.