Journal of Geology and Mining Research Vol. 4(4), pp. 65-74, May 2012
Available online at http://www.academicjournals.org/JGMR
DOI: 10.5897/JGMR11.042
ISSN 2006-9766 ©2012 Academic Journals

Full Length Research Paper

Acoustic velocity properties of Danian limestone section exposed at the Curfs quarry, Southeastern Netherlands

Ohwoghere Asuma, Oghenero

Department of Geology, Delta State University, Abraka, Delta State, Nigeria. E-mail: ohwonero@hotmail.com.

Accepted 15 March, 2012

In order to establish the relationship existing between the seismic velocity and petrophysical properties of limestone, ultrasonic pulse transmission technique under simulated pressure of 2.5 to 10 Mpa and at a frequency of 300 to 800 kHz was used in the determination of both compressional-wave and shear-wave velocities. The measurements were carried out for both dry and fluid saturated limestone obtained from the Curfs quarry in Limburg, Southeastern Netherlands. Compressional wave velocities values range from 2218.2 to 3280 ms^{-1} for dry samples and 2448 to 3730 ms^{-1} for fluid saturated samples. While those for shear-wave velocities values range from 2024 to 2982 ms^{-1} for dry samples and 1568.2 to 2024 for fluid saturated samples.These velocities values were used to constrained limestone into two lithogic units- the compacted limestone units, also know as the hardgrounds (high velocity values) and undercompacted limestone units (low velocity values). The compressional wave velocities of fluid saturated limestone samples are relatively higher than those obtained for equivalent dry ones, while the shear wave velocities of the same fluid saturated limestone samples were lower than the dry ones. The degree of diagnesis in the weakly cement limestone is responsible for the high value of both compressional- wave and shear wave velocities obtained from the acoustic velocity measurement. The velocity obtained from the time average equation is much more than the velocity obtained from the laboratory measurement of velocity for the curfs quarry.

Key words: Acoustic, compressional and shear-wave velocity, cement, fluid saturation.

INTRODUCTION

The ultilization of the knowledge of the relationships exsiting between seismic and petrophysical properties – permeability, porosity and the fabric of the reservoir rock are desired by reservoir geologists in the prediction of hydrocarbon bearing rocks. Predictions in sandstone have attracted more attentions compared to limestone in this regard. A simple reason attributable to the linear relationship that somehow exists between petrophysical and seismic properties of sandstone has to do with depth and this makes prediction direct and simple. This simple and direct prediction which is known to exist in siliciclastics is not associated with carbonate rocks, which therefore makes prediction of reservoir properties of carbonate often difficult (Assefa et al. 2003). On one hand, siliciclastics are made-up of interparticle porosity which often vary with depth, carbonate rocks on the other hand, are characteristized mainly by interparticle and intraparticle porosities which can further be subdivide into intercystalline microporosity, vuggy and moldic macro-porosities that may not vary with depth.

Assefa et al. (2003) demostrated that the prediction of petrophysical properties in carbonate is often difficult due to possession of complex textures and petrophysical properties- porosity and permeability, which are dependable and influenced by the diagenetic processes they may have undergone right from the time of deposition to the late diagenesis set in. In spite this, several investigations have been carried out in order to understand how transmission of sonic velocity is influenced by carbonate's complex textures, diagenesis, pore type, mineralogical composition and to established relationship between them and acoustic velocity.

Kuster and Toksoz (1974a, b), Anselmetti and Eberli (1993), Kenter and Reind (1997), Baechle et al. (2002) and Assefa et al. (2003), have revealed that the complex textures, porosity and permeability associated with carbonates rocks are attributable to different diagenetic processes, compaction, dissolution of skeletal grains, precipitation of new minerals and cementation. These processes have rendered the prediction of petrophysical properties for reservoir characterization difficult in carbonates than in siliciclastics (Assefa et al., 2003). However, certain studies that combined seismic, petrophysical and petrological data to established useful relationship between velocity and petrophysical of carbonate rocks were carried out by Rafavich et al. (1984) and Wilkens etal. (1984).

Anselmetti and Eberli (1993) obtained variation in both compressional and shear wave velocities; they attributed variation to the porosity, pore types and to a lesser extent on the mineral composition of the carbonate rock. Kenter and Reind (1997) also adduced velocity variation in carbonates to differential cementation and Baechle et al. (2002) to compaction, pore type, composition-insoluble and mud content. Kuster and Toksoz (1974a, b) demonstrated that limestone characterized by lesser aspect ratio, that is, the ratio of spherical to flat pore shapes, contribute more to variation observed in both compressional and shear velocities than spherical pores spaces. The work of Assefa et al. (2003) have also confirmed this in their study and ascertained that rocks possessing high aspect ratio pores tend to have high velocities than those with lesser aspect ratio.

The paper further investigates the result of the laboratory measurement of acoustic velocity in limestone core samples obtained from the Geulhemmerberg Member of the Houthem Formation, exposed at the Curfs quarry province of Limburg, Southeastern Netherlands. To further contribute and improve our understanding of the petrophysical properties of carbonate rock in relation to acoustic velocity, this study explores velocity data- both compresional and shear wave, combined with sedimentology and petrography; to characterized the carbonate lithology outcrop into different high and low velocity horizons.

Tectonic setting and Sedimentology

The tectonic setting of the study area can be traced chronologically from the Late Jurassic to the Early Cretaceous. During the Early to Middle Jurassic period the thermal Central North Dome resulted in the Mid Kimmerian Uplift which was succeeded by the development of unconformity due to the removal of older sequences (Herngreen and Wong, 2007).

The Collovian to Ryazanian time experienced increased heat flow, magmatic activity and faulting which emanated from the extension that characterised the Late Kimmerian. This period is known to have been associated with the formation of rift-like structures that formed the following basins; Dutch Central Graben, Central Netherlands Basin, Broad Fourteen Basin, West Netherlands Basin, Roer Valley Graben, Vlieland and Technelling basins and Lauwerszee Trough (Figure 1). In the Early Cretaceous thermal subsidence was recorded which was followed by marine transgression. The transgression was truncated by the Austrian tectonic in Early Albian and during the later part of Albian experienced another transgression. The Albian transgression was wide spread throughout the whole of Northwest Europe (Crittenden, 1987).

In Late Cretaceous there was drastic reduction in the amount of clastic sediments supply due to the flooding of the source area. This however, gave room for the growth of carbonate production which is the relicts of the carbonate platform of the Curfs quarry in the study area. Subsequent tectonic activities during the Subhercynian (Santonian-Campanian) and the Laramide paved way for increased different rate of subsidence as well as the tectonic inversion of earlier formed Jurassic Basins. Laramide tectonic inversion affected every part of the northwest Europe and occurred during the Paleocene. This time was characterized by reactivation of normal faults into reverse faults and massive erosion of uplifted basins fills that were the products of tectonic inversion as well as carbonate sedimentation which ended during this period (Table 1).

Different geological explanations were given for the possible causes of the tectonic inversion (Table 1). Ziegler (1982, 1990) suggested that it may have resulted from the Alpine compression. Baldschuhn et al. (1991) demonstrated that the transition from inversion to compression was not of regional scale but more of local scale, and finally, according to Kockel (2003), there was no plausible and convincing explanation for the inversion. Carbonates sedimentation eventually came to an end as a result of regional lithospheric tectonic deformation which triggered a sea level fall (Coetingh, 1986). Detailed sedimentological mapping of the vertical outcrop wall of the Curfs quarry revealed two prominent horizontally bedded lithofacies (Figure 7). One layer is predominantly hard in most of it part and is continuous throughout the quarry and soft in certain parts. The hardness is attributed to the consequences of sediments' strong lithification after deposition, eroded, bored by sponges and bivalves and encrusted with bryozoans, brachiopods and serpulid worms. It also consists of fine grains that are slightly porous, moderately cemented and finning upward. This layer is known as the hardground layer and there are several successions of it in the quarry. The hardground conspicuously overlies by incision-like coarse grained deposit or depression filled similar to storm deposit (Figure 7). In certain part of the Curfs quarry, the hardground layers are truncated as pinchout with certain coarser bioclast deposits that resemble storm deposits

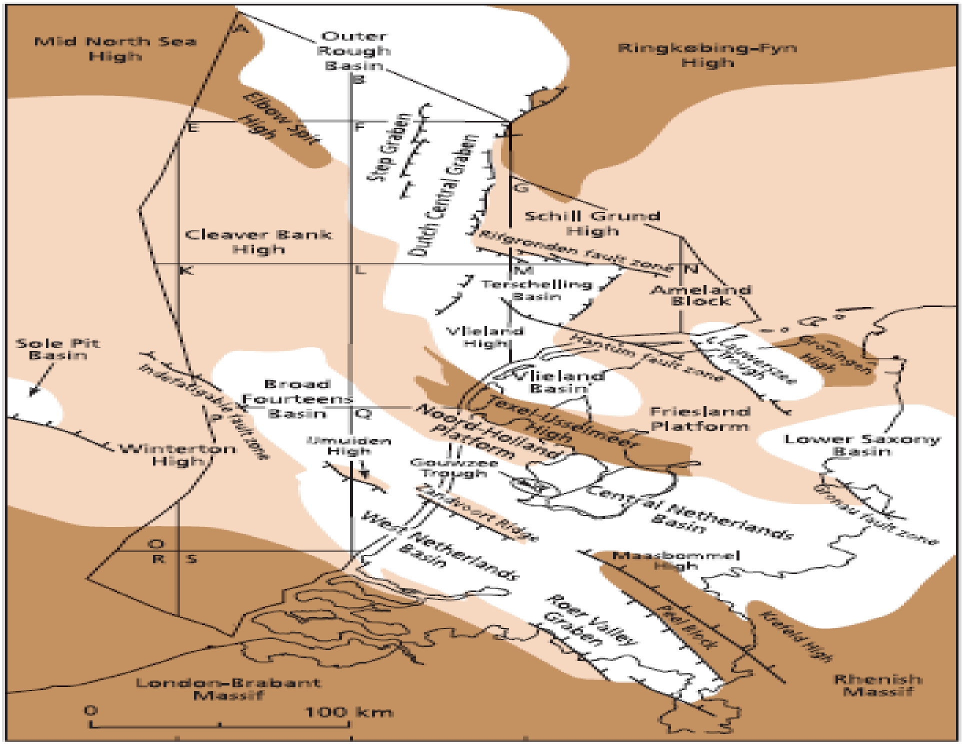

Figure 1. Map of Late Jurassic to Early Cretaceous structural elements in the Netherlands (Van Adrichem et at., 1993); dark brown, structural high partly subaerial landmass; light brown, platform; intermittently flooded, white basin.

(Figure 7). The hardgrounds are characterized heavily by the presence of numerous fossil assemblages and bioturbation, and consequently, lack sedimentary structures as intense bioturbation have obliterated them. The other facies are coarse grained carbonate sediments which are weakly cemented, whose grain sizes decrease upward. This layer is underlying the hardground and it is characterized by high porosity, poor cementation and it is highly uncompacted. Skeletal components of both facies consist of gastropods (echinoderms, bryozoans, serpulids, bivalves, corals and benthic foraminifera).

The colours of the outcrop vertical section of the Curfs quarry limestone deposit generally vary from yellowish, green to brown. The green and brown colours are attributable to the presence of detrital glauconite and iron minerals. Major sedimentary structures are lacking but there exist in the quarry traces of synsedimentary cross bedding, post Mastrichtian karst formation, bioturbation and burrows. The fossil assemblages depict variation of sizes which vary from large to small, which is an indication of transition from low energy to moderate energy of deposition. Shallow environment of deposition is therefore inferred for the Curfs quarry limestone deposit. The prevelant evironment of deposition existing at the time of deposition of the Limburg limestone, strongly suggest a tropical to subtropical environment as reflected by the assemblages of fossil encounter in petrographic study.

The Curfs quarry is located in Southwestern Limburg with a coordinates of 50° 45'17'' N and 60°15'' E. It borders the south and part of the west by Belgium, Germany to the east, Noord-Brabant partly to the west and the Geldland to the north (Figure 2). It is the only region in Netherlands characterized by carbonate platform.

MATERIALS AND METHODS

Cores were drilled paralell to bedding plane using water cooling diamond coring drill. Cylindrical shaped cores of different diameter and length in cm obtained for velocity measurement were put in a plastic bags and sealed. The differences in length and diameter is apparently due to the poor cementation nature of the samples as certain destruction of samples was experienced during coring, thus making it difficult to obtained a uniform diameter and length for the samples. A total of 8 cores were sucessfully drilled, with length that vary from 13.73 to 40.58 mm and diameter that vary from 35.78 to 38.02 mm. Rough cores sample were surface ground flat and prarellel to ± 0.005 mm. The section of the quarry outcrop where core samples were drilled were also described in the field and collected for petrographic analysis.

Ultrasonic pulse transmission technique for determining both compressional and shear wave velocities was used in the velocity measurement of core plugs.The experiment setup consists of a pulse generator, pressure vessel and digital oscilloscope. Compressional and shear waves velocities were generated from conversion of electrical pulse by a polarized piezoelectric ceramics. Core plugs

Table 1. Tectonic phases and the main event from Late Jurassic to earliest tertiary in the Netherlands (Ziegler, 1990).

Chronostratigraphy		Group	Tectonics phase	Events
Early Tertiary	Paleocene	Lower North sea	Laramide	Renewal of inversion tectonics; local erosion, minor rifting. Widespread carbonate sedimentation
Late Cretaceous	Maastrichtian Campanian Santonian Conacian Turonian Cenomanian	Chalk	Subhercyian	Strong inversion and erosion of Upper Jurassic depocentre; Regional differenecial subsidence. Onset of widespread carbonate sedimentaion
Early Cretaceous	Albain Aptian Barremian Hauterivian Valanginian Ryazanian	Rijnland	Austrian Late Kimmerian Phase II	Uncorformity; local uplift, folowed by erosion and regional Albian transgression. Onset of cretaceous transgression over “Late Kimmerian uncorformity” Diminishing rift activity; thermal subsidence
Late Jurassic		Schieland/Nedersachsen (Scruff)	Late Kimmerian Phase I	Major rifting and different subsidence; Rapid sedimentation over “Mid Kimmerian uncorformity in narrow and restricted basin; local volcanism

were subsequently subjected to the generated waves by high pressure measurement system (HPMS) with a frequency that vary from 300 to 800 kHz. Velocity measurement were made under both vacuum, dried and and fully staturated state. Fluid saturant was de-aired in distilled de-ionised water. Both the compressional-wave and shear-wave velocities obtained in the experiment were recorded from the digital oscilloscope. The confining pressure used in the experiment ranges from 2.5 to 10 Mpa due to the poorly cemented nature of the samples. Generally, confining the pressure up to 200 Mpa is possible for a study of this kind. However, a maximum of 10 Mpa was used for the study due to the undercompacted nature and some cores were destroyed in the process even at the confining pressure of 5.5 Mpa.

Samples for thin section analysis were obtained from core-plug samples and subsequently prepared in accordance with the standard of the tectonic and sedimentaology department of the Vrije Universiteit, Amsterdam. Grain size, texture and porosity type and cements were studied in a resin-impregnated polish section under plain-light petrography and catho-duluminescence.

RESULTS AND DISCUSSION

The results obtained from the acoustic velocitymeasurement for the eight core plugs are presented in Tables 2 and 3.

Acoustic velocity

The compressional wave velocities (Vp) for both the dry and wet limestone samples vary from 2242.5 to 3251.4 m/s and 2448 to 3730 m/s respectively (Table 2 and 3).While those for shear velocities (Vs) for both dry and fully saturated vary from 1976.4 to 2982.6 m/s and 1568.2 to 2022 m/s respectively. The compressional wave velocities are found to be greater than those of shear wave velocities of all the core plug samples determined. These values were then used to contrained the limestone into two lithologic units- the high and low velocity horizons. The higher velocitiy horizons were same as the lithified limestone unit, while the low velocity horizon corresponds to the weakly lithified limestone unit (Figure 7). This catigorization is in comformity with the obsevation made during outcrop study of the Curf quarry. The high velocity layer corresponds to

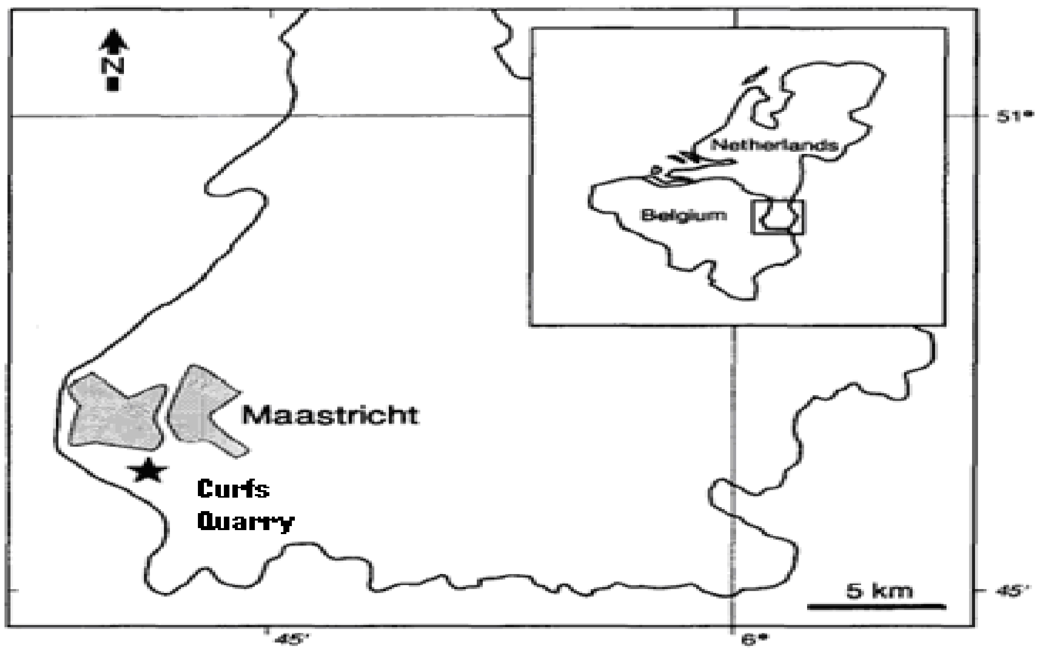

Figure 2. Map of the Limburg area, showing the study area (Schioler et al, 1997).

Table 2. Porosity fraction, compression and shear wave velocities for both dry and wet of unlithified limestone horizon.

Core plug sample	Bulk density	Porosity fraction	VP (m/s dry)	Vs (m/s dry)	Vp / Vs dry	Vp (m/s wet)	Vs (m/s wet)	Vs/vp wet
Cu-2	1.82	50.95	2242.25	2034.	1.102	2600.02	1893.5	1.3731
Cu-3	1.85	49.85	2364	2134	1.06	2448	1757.9	1.3926
Cu-6	1.80	53.25	2218.2	2024	1.20	2934.7	1641.7	1.7876

Table 3. Porosity fraction, compression and shear wave velocities for both dry and wet lithified limestone horizon.

Core plug sample	Bulk density	Porosity fraction	VP (m/s dry)	Vs (m/s dry)	Vp/Vs dry	Vp (m/s wet)	Vs (m/s wet)	Vp/Vs wet
Cu-1	2.14	32.45	3251.4	2643.8	1.22	3730	2022	1.8447
Cu-4	2.19	30.60	3280.6	2665.5	1.23	3550.9	2005	1.7710
Cu-5	2.00	34.95	3140.4	2567.8	1.22	3420	1946.9	1.7566
Cu-7	2.01	36.65	3233.2	2982.6	1.08	3506.7	1990.7	1.7615

the handground layers (lithified and hard) and the low velocity layer is equivalent of the fraible and soft layer (unlithified) overlying the handground layer. Furthermore, this distinctive difference in velocities is also explained from the geometry of the erosional surfaces of the limestone. The low velocity layer is characterized by undulating erosional surfaces (Figure 7); an indication of a soft and fraible limestone rock. This is distictive from the high velocity layers which have planer erosional surfaces; an indication of a stronger limestone (higher velocity units) than the overlying horizon (low velocity). The unlithified and the lithified limestone can be compared to the analogy of the depth of burial of limestone; that the deeper the depth of burial of the rock, the more compacted the rock is, and higher the wave velocity; the shallower the depth of burial, the lower the velocity. This behaviour is often associated with siliciclastic rocks, but this relationship is not common with carbonate rocks because of diagnetic alteration associated with them even at shallow depth, which can caused variation in acoustic velocity. Acuostic velocity in carbonate is usually influenced by factors of depositional lithology and many post-depositional processes, such as, cementation, dissolution or recrystallization (Baechle et al., 2002). The samples investigated are characterized by scanty quantity of cements and limited amount of dissolution (Figure 5) and as such the variation in cements may not have been totally responsible for the velocity variation observed, but the combined effects of the scanty cements, dissolution, porosity type and the pore types.

The compressional wave velocities of water saturated limestone samples are relatively higher than those obtained for equivalent dry samples on one hand (Tables 2 and 3; Figure 6); and on the other hand, the shear wave velocities of the same water saturated with limestone samples are lower than the dry samples. These two obvious observations are in accordance with the prediction theory; which states that, the compressional wave velocities of fully sturated fluid are higher than those of corresponding dry limestone. Also, the shear wave velocity of fully staurated limestone are lower than those corressponding dry limestone. This is not always the case as the theory depends on the pressure, porosity and fluid-mineral chemical reaction to which the rock has been subjected to. These factors however, were not considered in the prediction theory (Gregory, 1976). The observed variations in the values of velocities of Vp and Vs when saturated with water may probably attributed to rock/fluid interaction associated with rock in the subsurface. The time- average equation of Wyllie et al. (1956) was to matched the measured velocity. The velocities obtained from the time-average equation are higher than those from the labouratory measurement of velocity (Figures 4 and 5). This further comfirms the fact that many velocity prediction models such as the one previously mentioned, Gassmann (1951), Biot (1956), Raymer et al. (1980) etc., are usually used for the purpose of comparison. The reason for having higher elastic velocity than the measured one can be attributed to prediction made without the integration of the effects of chemical/physical interraction of the grains, minerals/ cements between the pore fluid of rock. For instance, the Gassmann equation (1951) used for the prediction of velocity is applied on the assumption that pores of the rock are interconnected, measurement is done at low frequency and fluid interraction that would alter the shear rigidity is not considered. In fact, the Gassmann theory suggests that the shear moduli of a dry rock is equal to the fluid staurated rock.

Furthermore, the compressional and the shear waves velocities of the water saturated limestone rocks were reducing as the porosity is increasing (Figures 3 and 4). This observation is in consistent with the findings of Tosaya and Nur (1982), Han et al. (1986) and Klimentos (1991), for sandstone and limestone by Rafavich et al. (1984), Wilkens et al. (1984) and Assefa et al. (2003). In spite of the fact that the samples investigated composed of high proportion of calcite mineral, there was variation in the ranges of VP and Vs; the Vp varies from 2218.3 to 3280.6 m/s and Vs ranges from 2024 to 2982.6 m/s. The variation is attributable to the amount of porosity and pore types in the limestone. In Figures 3 and 4, it was difficult to obtain the best-fit for the velocity-porosity plot, which is mainly becuase of the scattered points, adduced to the pore types that characterized the limestone investigated. This was further explains by the works of Anselmetti and Eberli (1999), which demostrated the clustering of dominant pore types in velocity-porosity diagram when dominant pore type is assigned to individual samples. The acoustic properties of these varieties of pore types show why rocks with same porosity can have different porosities. In addition, Baechle et al. (2002), has shown that limestones which are characterized by dominant moldic porosity tend to have velocities which are over 2500 m/s faster than limestone with dominant interparticle porosity. While limestone with moldic and intraframe porosity have positive departure from the general trend; whereas, rocks with interparticle, intercrystalline or microporosity have low velocity and show negative deviation. The limestone investigated is characterized by interparticle porosity type which is many times more dominant that the intraparticle type. This is probably why the samples investigated are characterized by low velocity values, which are less than 400 m/s. According to Baechle et al. (2002), large scattering of velocities at same porosity makes duduction of porosity cubes from sonic velocity difficult during seismic inversion

The ratio of compressional wave velocity to shear wave velocity (Vp/Vs) for water saturated limestone samples were calculated for both the weakly cemented limestone and poorly cemented limestone. The values obtained ranges from 1.75 to 1.84 m/s and 1.37 to 2.14 m/s respectively, and these values are not influnced by the porosity (Tables 2 and 3). These values are consistent with those obtained by Assefa et al. (2002), but different from those obtained by Rafavich et al, (1984).

The different between the values of the ratio of VP and Vs in this study and the later one lies on the mineral composition of the limestone. While the later is dorminantly made up of dolomite, and the sample investigated is made up largely by calcite in composition. Thus, butressing the fact that the percentage of minerals present in a particular limestone also affect the compressional wave and shear wave velocity of both dry and fluid- saturated one.

Mineralogically, the limestone investigated consists mainly of bioclastic calcite, minor quartz, galuconite and pyrites. The limestone is characterized by medium-fine–coarse grainstone, packstone and wackstone that are mainly subangular and poorly sorted in both the lithified and unlithified. Majority of the pore types are of interparticle type with irregular shapes, branching, and therefore the pore geometry of the limestone is very complex

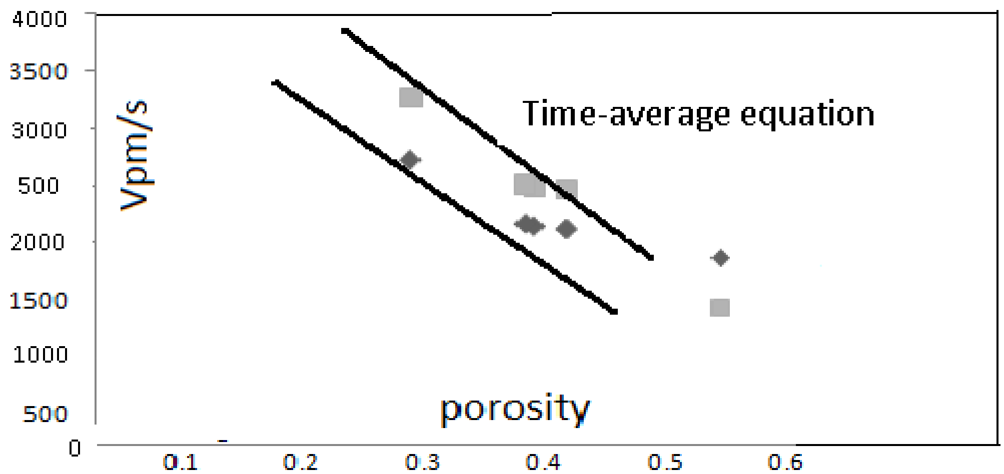

Figure 3. Compressional-wave veocity/porosity plot for the poorly cemented limestones samples and the time-average equation that overestimate velocity.

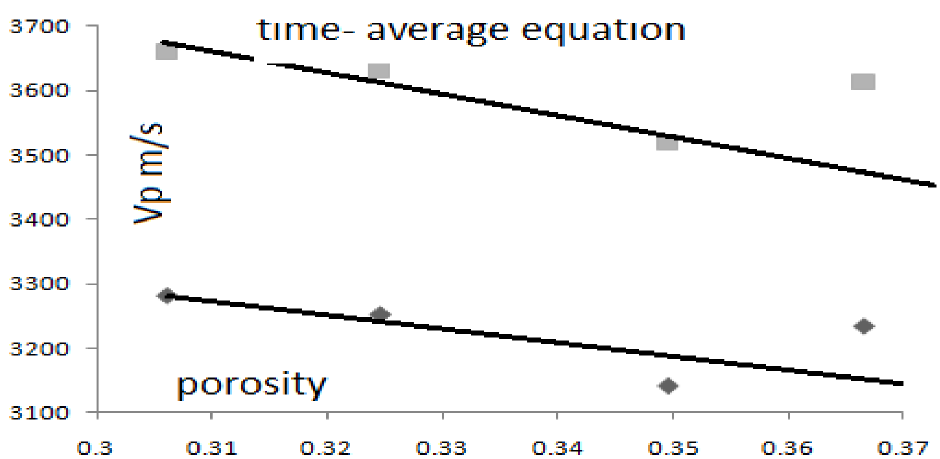

Figure 4. Compressional-wave veocity/porosity plot for the weakly cemented limestones and the time-average equation that overestimate velocity.

as no dominant type predominate over the other because of the irregular pore shapes (Figure 5). The compositional plot of compression wave velocity andporosity of the limestone under investigation is shown in Figures 3 and 4. The relationship between compressional wave and shear wave velocities and pore geometry of limestone rocks has already be established by Assefa et al. (2003). They were able to deduce a relationship between aspect ratio – the ratio of large spherical pores shape to that of a small oblate pore shape; they demostrated that, as the rate of velocity increases with correponding increase in pressure, carbonate rocks with high preponderance of high aspect ratio tend to have lower acoustic velocity than that those of low aspect ratio.

Early diagenetic micritization and blackening (pyritization) of bioclastic particles are quite common. Most of sample is characterized by glauconite, whose colour ranges from orange (oxidized) to green (non-oxidized). Glauconite occured as detrital pelliodal grains, in bioclast and inbetween pore spaces. Certain part of grains have been dissolved on exposure to meteioric groundwater. Some pores are often lined with very fine-crystalline fabrous calcite rim cements, poikilotopic, syntaxial cements predominantly found around echino-derm clasts (Figure 5). Quantatively, the limestone investigated consists of scanty amount of cements, a siginficant large amount of cements is dominantly more in the lithified limestone-the hardground (high velocity layer) than the unlithified limestone-fraible limestone(low velocity layer). Consequently, Kenter et al. (1997) has suggested differential cementation between the harground limestone and the fraible layer is reponsible for

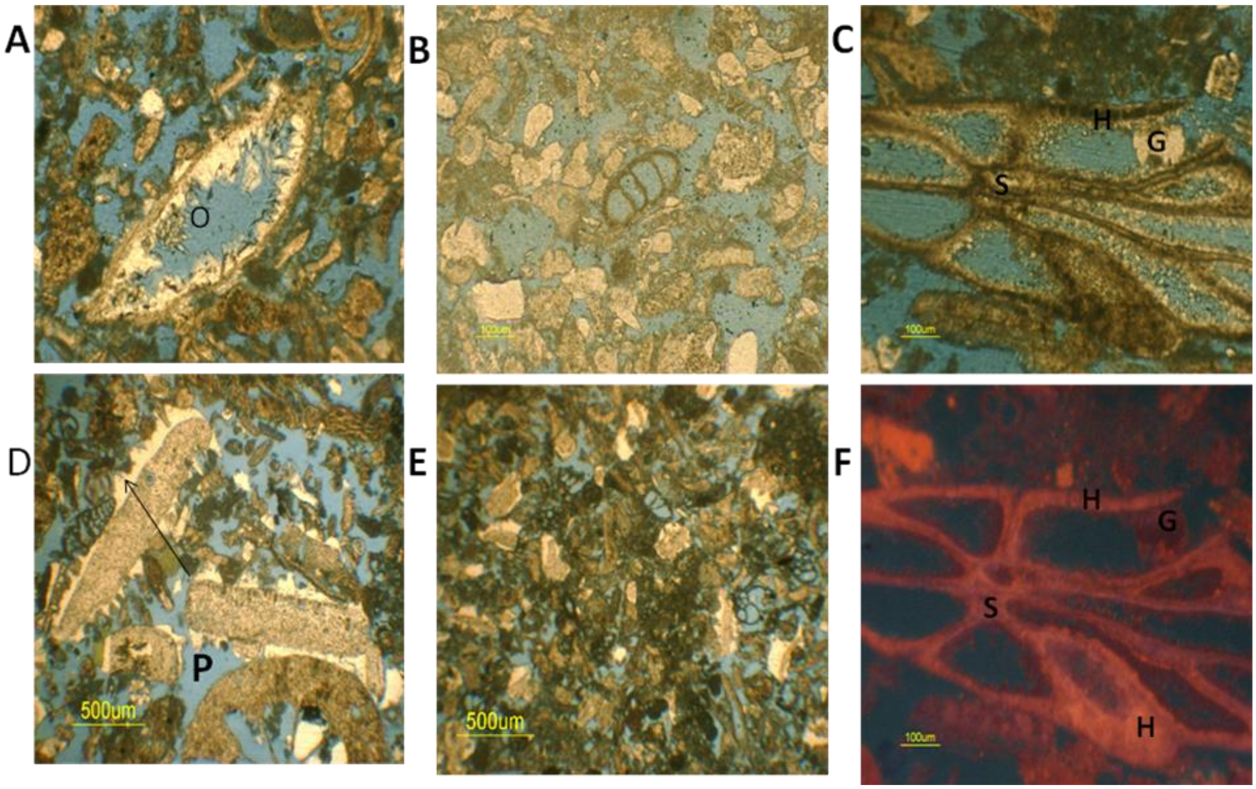

Figure 5. Photomicrographs: (A) medium to fined, poorly sorted and porus grained calarenite, with lipidorbitoides, interparticle and intraparticle porosity type(o) formed due to dissolution, micritization before dissolution and syntaxial overgrowth rim cements, (B) is porous medium to fine grain calcarenite with black benthic forminifera with interparticle porosity and micrite, thin and fibrous cements and more, (C) poorly sorted porous medium to fine grained calacarenite with bryozoan clast with intragranular walls chambers with small euhedral calcite cement that is found in the inner wall of the chambers, H is a micrite cement and scalenohedral cement, G and S are intra cements (blocky calcite cement), micritization, follows by dissolution before precipation og cements; while F, is the cathodoluminescence of G, showing three generation of cements; G = dark cement, S = dull cement and H = bright cments (sequence of cement development), (D) microphotograph of sample echinoids fragments that are highly cemented at grains' contact with syntaxial cement with some grains that are completely replaced with green coloured and brown prytized gluconite and some micrites envelopes cementing benthic foraminifera, (E) is slightly sorted, porous fine to medium calccarenite with moderate quantity of benthic foraminferae, heavily micritized with thin and fabrous rim of calcite cements and syntaxial cements; the interparticle porosity dominated intraparticle porosity type.

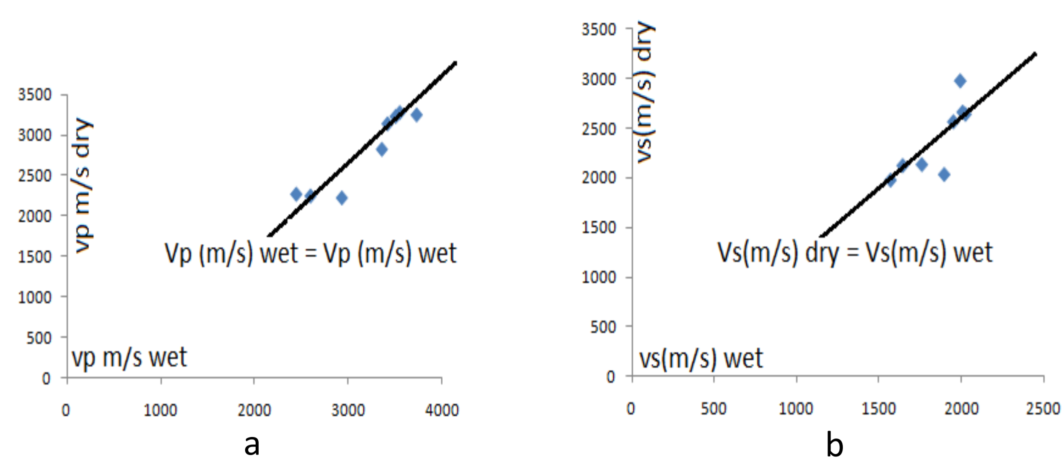

Figure 6. a, compression wave velocity for both dry and water saturated; b, shear wave velocity for both dry and wet.

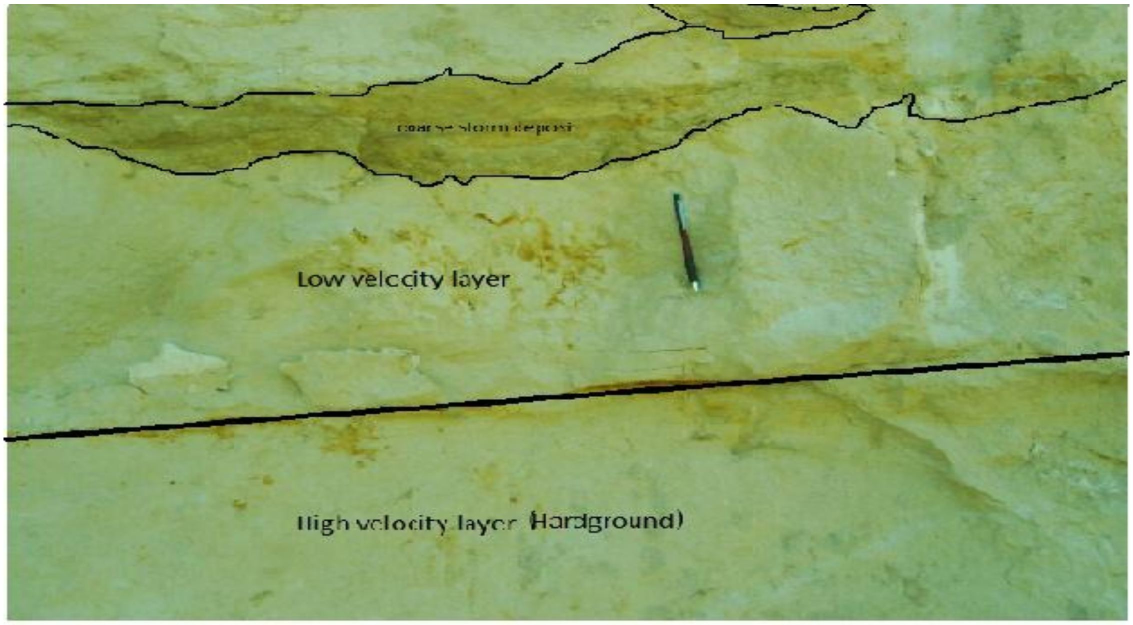

Figure 7. A section of the the Curf quarry depicting high velocity layer (hardground), slightly above the hardgorund is the low velocity layer (pencil) above this is deposit in a depression fill that is similar to storm deposit. Scale is the length of pencil, dark lines represent erosional surfaces and boundaries between limestone layers and depression fills.

the variation in velocities recorded in the Blom quarry. This may be partially true as the type of cements is more impotant than the total amount of cements. This study tend to aligned with the later statement, because in the Curfs quarry, there exist different type of cement as shown (Figure 5); and this different cements will have their effects on the velocity. This has been well illustrated by Baechle et al. (2002) that, acicular rim cements commonly formed in shallow marine environment do not contribute to the rgidity of coarse-grained material as effectively as micritized intergranular cements. As a result, samples with with different cements types may have similar amount of total cements, but surprisely different acoustic velocities.

In order to further explains the acoustic properties and the behaviour of carbonate rocks, the acoustic properties of Miocene – Pliocene carbonate rocks of the Western Great Bahama Bank studied by Kenter et al. 2002, was compared with the acoustic velocity obtained from the study. Unlike the Danian rock of the Curfs quarry which are dominantly composed of skeletal grainstone, the pliocene rocks are dominantly composed dominantly of packstone to wackstone, however, both sediments were derived from shallow- water depositional environments. Also, both are characterized by stratigraphic units, whose lithologies are uncemented and undercompacted, and cemented and lithified limestones.

The Western Great Bahama Bank carbonate rocks are characterized by higher velocities than those of this study. The acoustic velocity in this study vary between 2.2 and 2.8 km/s for unlithified and less cemented limestone and 3.1 to 3.3 km/s for the lithified and cemented limestone. However, the uncemented and uncompacted background sediments of the Miocene–pliocene have acoustic velocities that range between 2 and 4 km/s and the cemented calciturbidites whose velocities range from 2 to 6 km/s. It was concluded from the comparison that the acoustic properties of unlithified limestone within a specific depositional environment are quite different from thier lithified counterparts.

Conclusion

The compressional and shear wave velocities obtained from the laboratory were sucessfully ultilized to constrained the Limburg limestone deposit exposed at the Curfs quarry into two stratigraphic units. These are the core plug limestone samples in which the acoustic velocity of transmission through them is relatively high and the other with low velocity. These two stratigraphic units correspond similarly to those samples that posses low porosity values, which are compacted and hard (high velocity), and those with high porosity, which are undercompacted, fraible and loose (low velocity). The unlithified limestones tend to be different from thier lithified counterparts in terms of petrophysical properties under specific environmental of deposition as shown from the comparison between Plioecene rocks of the Western Great bank with the Limburg limestone. The total amount of cement in both the lithified and unlithified limestone units may not be responsible for the variation in the values of acoustic velocities alone but combined effect of type of cements, the porosity and pore types as well as the composition of the limestone. The diagenetic changes which are often associated with carbonate rocks and which alter their petrophysical properties before compaction set in, tend to render the estimation of downhole velocity from them, difficult.

Acoustic velocities properties predicted from a give porosity are often in variance with those obtained from labaoratory measurements. Thus, the compressional-wave velocity predicted by the time-average equation are higher than those obtained from the laboratory measurement. The time-average equation therefore over-estimated the compressional-wave velocity in this study, because it does not take into consideration the variation arising from the matrix/fluid interaction of limestone that are associated with fine grained sediments, which the laboratory measurement does.

REFERENCES

Anselmetti FS, Eberli GP (1993). Control on Sonic Velocity in Carbonates. Pure Appl. Geophys., 141: 287-323

Assefa S, Mccann C, Sothcott J (2003). Velocity of Compressional and Shear waves in limestone. Geophysical Prospecting, 51(1): 1-13.

Baechle GT, Anselmetti FS, Eberli GP, Ineze ML, Gartner GB (2002). Factors controlling elastic properties in carbonate sediments and rocks, workshop: geophysical application to carbonates reservoirs, SEG,Annual Meeting, Salt Lake City Utah.

Baldschuhn R, Best G, Kockel F (1991). Inversion tectonics in the Northwest German Basin.In: Spencer,A.M.(ed):Generation, accumulation and production of Europe hydrocarbons. Special publication. European Association of Petroleum Geologists. Oxford University press (oxford), 1: 145-159.

Biot MA (1956). Theory of propagation of elastic waves ina fluid saturated porous solid 11, low frequency range. J. Acoustical Soc. Am., 28: 168-178.

Coetingh S (1986). Intraplate stresses: a new tectonic mechanism for fluctuation of relative sea level. Geology, 14: 617 -620.

Crittenden S (1987). The Albian transgression in the southern North Sea Basin, J. Pet. Geol., 19: 395-414.

Gassmann E (1951). Uber die Elastizitat ProoserMedion. Vierteliabress chrift der Naturforschbeden Gesellschaft in Zurich, 96: 1-23.

Gregory AR (1976). Fluid saturation effects on dynamic elastics properties of sedimentary rocks. Geophysics, 41: 895-921.

Han D, Nur A, Morgan D (1986). effects of porosity and clay content on wave velocity in sandstones.Geophysics, 51: 2093-2107.

Herngreen GFW, Wong THE (2007). Cretaceous: In Geology of the Netherlands. Royal Netherlands of arts and science. pp. 127-150.

Kenter JAM, Anselmetti FS, Krammer PH, Westphall H, Vandamme MGM (2002). Acoustic Properties of ,''Young'' Carbonate rocks, ODP LEG 166 and Boreholes Clino and Unda, Western Great Bahama Bank. J. Sediment. Res., 72(1): 129-137.

Kenter JAM, Reinder M (1997). Effects of differential cementation on the sonic velocities of upper Cretaceous skeletal grainstones Southerneastern Netherlands. J. Sedimentol. Res., 67: 178-185

Klimentos T (1991). The effect of porosity – permeability-clays content on the velocity of compressional waves. Geophysics, 56: 1930-1939.

Kockel F (2003). Inversion structures in Central Europe Expression and reasons, an open discussion. Netherlands J. Geosci./ Geologie en Mijnbouw, 82: 351-366.

Kuster GT, Toksoz MN (1974a). Velocity and attenuation of seismic waves in two-phase media; Part 1 theoretical formulation. Geophysics, 39: 588-606.

Kuster GT, Toksoz MN (1974b). Velocity and attenuation of seismic waves in two-phase media; part 11, experimental results geophysics 39: 607-618.

Rafavich F, Kendall C, Todd T (1984). The relationship between acoustic properties and petrographyic character of carbonaye rocks. Geophysics, 49: 1622-1636.

Raymer LL, Hunt ER, Gardner JS (1980). An improved sonic transit time to porosity transform.21st SPWLA Annual Meeting, pp. 1-13.

Schioler P, Brinkhuis H, Roncaglia L, Wilson GJ (1997). Dinoflagellate biostratigraphy and sequence stratigraphy of the type Maastrichtian (upper Cretaceous, ENCI, The Netherlands. Marine Micropaleontonlogy, 31: 65-95.

Tosaya C, Nur A (1982). effects of diagenesis and clays on compressional wave velocities in rocks. Geophys. Res.Lett. 9: 5-8.

Van A, Boogaert HA, Kouwe WFP (1992-1997 eds.). Stratigraphic Nomenclature of the Netherlands revision and update by RGD and NOGEPA, Mededlingen,Rijks Geologische Dients, nr. 50.

Wilkens R, Simmons G, Caruso L (1984). The ratio vp/vs as a discriminant of composition for silicious limestone. Geophysics, 49: 1850-1860.

Wyllie MR, Gregory AR Gardner GHF (1956). Elastic wave velocity in heterogenous and porous media. Geophysics, 21: 41- 70.

Ziegler JJP (1994). Sedimentology of the Late Cretaceous and Early Tertiary (tuffaceous) chalk of Northwest Europe. Geolgica Ultraiectina 199: 1-192.

Ziegler PA (1990). Geological Atlas of Western and Central Europe (2nd edition) shell internationale petroleum maatschappij BV: Geological society publishing House (bath); p. 239.

Ziegler PA (1982). Geological Atlas of Western and Central Europe. Shell Internationale Petroleum Maatschappij BV., distributed by Elsevier Amsterdam: p. 130.