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THE EFFECT OF GRAIN SIZE DISTRIBUTIONS ON ACCOUSTIC WAVE VELOCITIES IN POROUS ROCKS

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Abstract:

Several cores of Malaysian sand stones and Indonesian limestone from out croup are prepared to determine their grain size distribution from SEM (Scanning Electron Microscope) Unit and section core to determined acoustic velocity Compressional and shear wave by I Mhz transducer a coustic Pundit (Pulse Ultrasonic Non Destructive Unit) Plus Unit in laboratories. Reservoir rocks arc mostly consisting of porous sedimentary rock. There are fewimportant characteristics of reservoir rocks in petroleum industry that need to be studied for further development Among them are petrophysical properties such as acoustic velocity by using acoustic log and seismic by determined density and, porosity. In this study tests have been carried out to examine the relationship between grain size dislribution and acoustic velocity using Ultrasonic Pulse Velocity Method (UPVM). Result of the laboratory test have been used to determine of porosity of porous rock from acoustic velocity data.

Key words: grain size, acoustic wave velocity

I. INDRODUCTION

Advances in acoustic wave and sonic logging technology have resulted in enhanced formation eva1uation capabilities. Acoustic wave velocities in reservoir rocks depend on many parameters, for example, grain size distribution, porosity, pore fluid properties and level of saturation, lithology, clay content, pore structure and geometry and other physical characteristics. The application of acoustic and sonic wave technology in the petroleum industry bas been limited to measurement of compressional and shear waves. Compressional and shear waves correspond respectively to particle vibration parallel and perpendicular to the direction of wave travel. Acoustic wave measurement in the laboratory and in the field have been used for various applications ranging from determination of porosity, interpretation and calibration of sonic logs. Identification of lithology, determination of classical elastic rock parameter and formation, enhanced seismic interpretation, micro fracture recognition and formation damage evaluation.

Acoustic wave from seismic and sonic well log, can be correlation from acoustic wave from ultrasonic data in the laboratory. Ultrasonic tester is non destructive testing, and than core sample is not franc (non destructive), whit use correlation acoustic velocity from data test versus physical rock properties can be determine of characteristic of rock can be drill, stimulation (fracturing), and evaluated of reservoir rock. The parameters of rock physical properties can measured by using two methods, laboratory test and well log analysis. In this paper to study how determined physical rock properties from acoustic velocity tester. As is well know in this tester is non destructive testing, on the other band core sample is not leak.

This study can be predict correlation of grain size distribution for several Malaysian sandstone and

Indonesian limestone versus velocity of rock. Acoustic tools use sound to can be measured different characteristics of rock and the sonic tool is used in calculate density and porosity.

II. LITERATURE REVIEW

M.S. King, M.Sbams Khanshir and M.H. Wollington , as study of correlation acoustic with rock properties, as the topic : Petrophysics studies of core from a cross bole seismic test site (1991). Four vertical boreholes of 260 m depth have been drilled through five cyclical sequences of shallow-dipping sandstone, clay stone and lime stone formation [2].

The velocity in a rock may be related with the velocities in its various grain size and mineral components. Therefore, it is apt to discuss briefly about these two properties in order to understand the relationship between wave propagation and rock texture. Grains are the particles which support the framework of a rock. They are thus generally of sand grade or larger (Friedman and Sanders, 1978) [5,6).

The effect of average grain size and sorting on porosity and permeability has been examined periodically. Graton and Fraser (1935) showed that porosity of uniformly sized spheres but are affected by the packing arrangement. However, studies of natural sands and gravels indicate porosity is greater in fine- grained sands than in coarse-grained sands (Lee 1919; Todd 1959). Griffiths (1952) examined the grain size distribution in various reservoir rocks and concluded that no generalized statement could be made as to the effects of size and sorting on porosity and permeability. Rogers and Head (1961) in a study of synthetic sands concluded that in well sorted sands, porosity is independent of actual grain size (Hayes, 1977)[8,15,16].

Theoretically, porosity is independent of grain size. A mass of spheres of uniform sorting and packing will have the same porosity, regardless of the size nfthe spheres. The volume of pore space varies in direct proportion to the volume of the spheres. Finer sands tend to be more angular and to be able to support looser packing fabrics, hence they may have a higher porosity than coarser sands (Friedman and Sanders, 1978)[5,6].

Whatever the cause of the relationship, it has been shown empirically that porosity generally increases with decreasing grain size for unconsolidated sands of uniform grain size. Permeability, by contrast, increases with increasing grain size (Fraser, 1935; Krumbein and Monk, 1942; Pryor, 1973). This is because in finer sediments the throat passages between pores are smaller and the higher capillary attraction of the walls inhibits fluid flow. This relationship is fouad in both unconsolidated and lithified (composite) sand (Friedman and Sanders, 1978)[5,6].

The velocity of waves is influenced by the size of the grains constituting the rock. The velocity is greater as a rule in fine-grained rocks than in coarse-grained ones. Because, as been said that finer sediments tends to have smaller throat passages, (grains is well- packed, leaves a compact medium for wave propagation) allow the acoustic wave to propagate faster than in the coarse-grained and loose packing rocks.

The scanning electron microscope (SEM) is an instrument that is routinely used for the production of strongly enlarged images of a specimen. The maximum. The maximum achievable magnification of the SEM lies between that of the normal light microscope (LM) and transmission electron microscope (TEM). It is not, however, the magnification capabilities alone that have led to the SEM being such an important and widely used analytical tool. The exceptional depth of field, minimal specimen preparation (compared with that required for TEM investigations) and the ability to combine the technique with x-ray micro analysis have all been contributing factors. Specimens observed in the SEM under higher magnifications than are possible with the optical microscopes showed surface features not previously recognized (Levinson, 1977)(15,16].

SEM has been used to determine types of porosity, the nature of permeability, microcrystalline overgrowths and the size of crystals or fragments in microcrystal line and amorphous rocks. In this study, SEM is applied to verify the grain size of each core samples.

III. METHODOLOGY

3.1. SAMPLE PREPARATION

A total of forty-five samples of sandstone and limestone namely S, R and E were taken from Sarawak, Rompin, Pahang and Indonesia basin respectively. Sandstone samples are from Sarawak and Rompin while limestone samples were taken from Indonesia. Three sets of experiment have been carried out, which are SEM Test, Porosity Test and Acoustic Velocity Test.

Sample Malaysian sandstone and Indonesian limestone of I inch diameter and length 1 inch were cored in the laboratory from out croup from the preserved core. The samples is conditioning to oven at 60 ° C during 8 hours and than sample to test density and porosity versus acoustic compressional wave velocity with Pundit. This procedure permits the measurement of both P wave velocities for preserved core samples obtained perpendicular to the bedding. Sample preparation involves coring and samples for Scanning Electron Microscope (SEM) Test.

Coring Sample

The coring machine has been used along with Iinch iron bit As a result, the cylinder shapes of cores with linch diameter. Then by using the cutter machine, the cores were cut into I to 1.5 inches length. To ensure there are no fluid left in the cores, all the cores has been heated in an oven for 8 hours in 60°C. Core preparation were based on ASTM (ASTM 04543-85). The bulk volume were determined by using the following equation,

$$v_b = 3.142\ (d/2)^2 \qquad (1)$$

Where v_b = bulk volume, d = diameter of core samples, L = length of core samples and 3.142 constant

Sample for SEM Test

A piece of rocks were taken :from each samples and were crushed into 'individual grain' separately. The grains then were scattered onto piece of double-sided tape which attached to a specimen pedestal to produce only a thin layer of grain and labeled as S, R and E samples.

The specimens are coated with gold by thin film deposition, to give the surface electrical conductivity. Thickness of the coating is 100 to 200 angstroms, so thin that the coating does not mask true surface features.

3.2. PROSEDURE TEST

3.2.1. SCANNING ELECTRON MICROSCOPE TEST

SEM Test is important to know the size of grain that forms the rock samples. The effect of grain size on porosity would be resolute from the results of the test The steps to precede the SEM test are as below.

1. The labeled sample is put inside a vacuum chamber.
2. Vacuum pump is switched on to discharge any gas inside the chamber.
3. Finely focused electron beam (lOOA) will scan the specimen surface.
4. Interaction of the electron beam with the specimen surface generates a signal that results ultimately in brightness modulation, thereby producing an image of the specimen surface (SEM image).
5. Grain sire were measured from both X and Y-axis of SEM image.
6. The grain size data are recorded.

3.2.2. HELIUM POROSITY TEST

The porosity of rock depicts the dimension of pore space of a rock filled by fluid, either oil or gas or water or a combination of the fluid. In laboratory, the porosity of a rock can be measured using both porosimeter and weighting method. The porosity of rock can be formulated in dimensionless equation (percent or fraction), that is the ratio between pore volume (V_p) with total volwne of a rock (V_b). It can be written mathematically as follows

The methodology to determine. the porosity of dry samples is shown below.

1. The source of helium gas from the tank is connected to the panel with all valves of the tool are closed.
2. The core sample is placed in the core bolder followed by the discs until it become leveled or slightly lower than the matrix container (core bolder). Theo, the container is tightening in its place.
3. The source and supply valve are open until the pointer is pointing at 100 psi (if not, use the regulator to adjust the pointer). Both valves are then closed.
4. By opening the core holder valve, the movement of the pointer is observed to move anti-clock-wise.
5. Then, when the pointer stops moving, the reading at the outer scale of the Porositymeter are recorded. Moreover, this is the 'volume with sample' (core sample volume + discs). Gauge reading are taken.
6. The core holder valve is closed to ensure the gas cannot escape.
7. The exhaust valve is now open to allow Opsi inside the matrix container.
8. By loosening the cap, get the core sample out of the core bolder and tighten the cap again with the disc are inside.
9. Steps 3 to 7 are repeated to get the 'volume without sample' (the volume of disc). Gauge reading is taken as 'volume without sample'.
10. Steps 2 to 9 are repeated for another core samples.

Porosity is calculated using Equation (3).

$$\Phi = \frac{Vp}{Vb} \quad (2)$$

$$\Phi = (V_b-V_g)/ V_b \text{ x } 100\% \quad (3)$$

Where Φ = porosity, V_b = bulk volume and V_g = grain volume

3.2.3. ACOUSTIC TEST

The ultrasonic wave include mechanical vibration type is involve to various mechanical forces in transit in a medium of rock. Effect of acoustic wave depend to mediwn elasticity spreading. The transit time of rock is the mine , how long necessary of acoustic velocity transit at a rock in length dimension, in µ sec I ft. The transit time the equal reverse with acoustic velocity of wave in the rock.

Transit time of rock to determined in mathematical equation as follow :

$$\Delta tma = 1/Vma \times 10^6 \quad (4)$$

when : Δtma = transit time, μ sec/ft and Vma = acoustic of velocity wave in the rock, ft /sec

Method of testing for assessing the quality of materials from ultrasonic pulse velocity measurement, it is necessary for this measurement to be of a high order of accuracy. This is done" using an apparatus which generates suitable pulses and accurately measures the time of their transmission (i.e. transit time) through the material tested. The distance which the pulses travel in the, material (i.e. the path length) must also be measured to enable the velocity. Path lengths and transit times should each be measured to an accuracy of about 1 %.

The instrument indicates the time taken for the earliest part of the pulse to reach the receiving transducer measured from the time it leaves the transmitting transducer when these transducers arc placed at suitable points on the surface of the material. In this research of ultrasonic method can be determine, is direct method , when the surface of the specimens tasted direct contact whit transducer

The direct transmission arrangement is the most satisfactory one since the longitudinal pulses 1 leaving the transmitter are propagated mainly in the direction normal to the transducer face. Analysis condition is a material with ultrasonic wave is Non Destructive Test (NDT) TesL Principal is work as : Electrical wave energy from generator pulse to transfer from transducer (Tx) as mechanical wave, and than can spreading in sample of rock (material). After reaching the receiver transducer (Rx), the wave energy can be retransformed to electrical wave by transducer (Rx) and then it is spread through booster and finally to determined time transit by digital numerical or oscilloscope.

From these values have to be subtracted the times, Alp, required for the P wave pulses just to traverse the transducer holders and brass end pieces them selves. These values arc obtained prior to the tests with. rock specimens, by placing. the transducer holders and end pieces in face-to-face contact with a disc of lead foil between them and. establishing the times of flight, Δ tp for P waves. The velocities arc calculated by dividing the length of the specimen, L, by the appropriate 'pulse time-of-flight, corrected for Δ tp. Portable Ultrasonic Non-Destructive Digital Tester (PUNDIT) is a pulsing unit that being used in this study to obtain the acoustic velocity of rocks. Using a frequency of 1 MHz, the compressional wave (P-wave) and shear wave (S-wave) velocities arc calculated by dividing the length of the specimen, L by the appropriate pulse time-of-flight :

$$V_p = L / t_p \text{ and } V_s = L / t_s \quad (5)$$

Where Vp = P-wave velocity, Vs = S-wave velocity, L = length of specimen and tp and ts = transit time compressional and shear wave (pulse time-of-flight)

IV. RESULT & DISCUSSION

Several sets of experiment have been carried out. In order to achieve the correlation between acoustic velocity and porosity, some factors which are now is identified as factors that affecting the correlation will be discussed in this chapter. The discussion will include the results of petrography test, porosity tests and acoustic velocity tests. The distribution of grain size of the samples has been determined by scanning electron microscope (SEM) test, And acoustic velocity test by PUNDIT Plus Unit with I MHz P & S Wave transducer.

Figure 1, 2 and 3 shows the grain size distribution for Sarawak samples, Pahang Samples and Indonesia samples respectively.

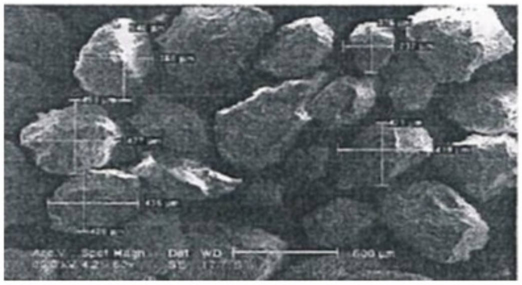

Figure 1: SEM image for sandstone Sarawak sample.

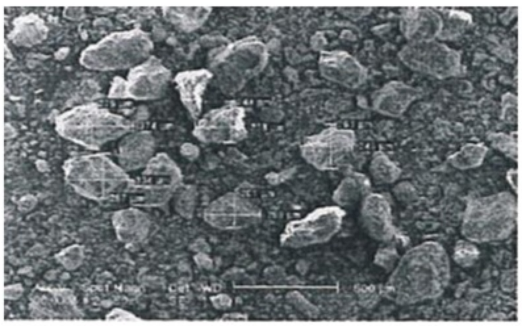

Figure 2: SEM image for sandstone Rompin, Pahang

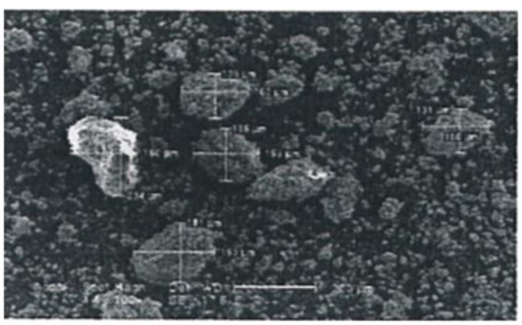

Figure 3: SEM image for limestone Indonesia.

Based on these images, the distributions of grain size are as below;

- Sandstone Sarawak: ranges between 286.5µm to 487.5µm.,Average grain size: 418.5µm.
- Sandstone Pabang : ranges between 235µm to 324.5µm, Average grain size: 268.3µm
- Limestone Indonesia : ranges between 145.5 µm to 197 µm, Average grain size : 167.1 µm

From the analysis, it shows that sandstone Sarawak samples have the biggest grain, followed by sandstone Pahang samples, and the smallest grain size for limestone Indonesia samples. Figure 4 and 5 shows graph acoustic velocity versus grain size for each sample using P-wave and S-wave respectively. Both graphs show that acoustic velocity decrease when grain size increase. This is true to the theory which stated that velocity is greater as a rule in fine-grained rocks than in coarse-grained rocks (R.D.Lama & V.S.Vutukuri, 1978).

The inversely proportional between acoustic velocity and grain size is due to the space between grains. Acoustic waves need medium to travel which is to say the grains. Less grain allow more air between them, and air is not a good medium to transfer acoustic wave. The results of using P-wave and S-wave are same although the velocity of Swavc is slower than P-wave velocity. The factor correction in this result equation between R = 0.8492 to R= 0.9683 as significant phenomenon at linear equation.

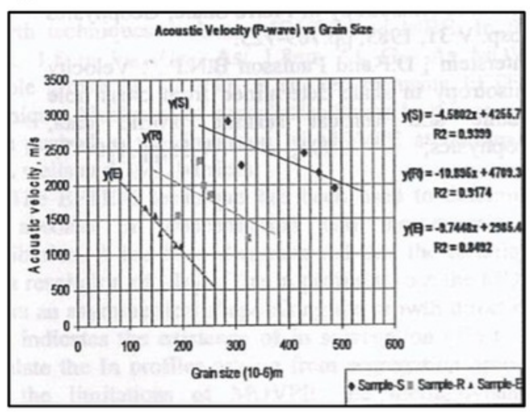

Figure 4: Graph acoustic velocity by using P-wave versus grain size distribution of each sample

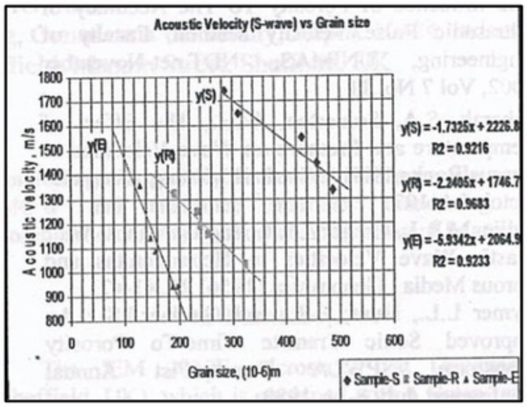

Figure 5: Graph acoustic velocity by using S wave versus grain size distribution of each sample

V. CONCLUSION

This study of focuses principally on the effect grain size distribution of rocks to acoustic wave velocity can be outline result as follows :

- The greater increasing grain size distribution of rocks to effect decreasing acoustic wave velocity
- Sandstone Sarawak samples has the biggest grain size distribution, followed by sandstone Pabang samples and smallest grain size distribution is limestone Indonesia.

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