Using ultrasonic technique to determine some petrophysical properties of core samples of Zubair and Mishrif Formations at Lu-5 and Tu-5 oil wells, southern Iraq

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Abstract

Seventeen core samples were taken from Luhais and Tuba oil wells according to the presence of oil bearing formations. These wells were located in the province of Basra/southern Iraq. The formation that the samples are collected from Zubair and Mishrif formations. The core samples were taken from the wells at different depths. In the current study the ultrasonic technique was conducted to measure (Vp and Vs) as well as to determine some petrophysical properties for core samples and some elastic moduli such as (Young's modulus, Bulk modulus, Shear modulus, Poisson's ratio and Lame's constant) depending on the values of Vp and Vs as well as density. The relationships between seismic wave velocities with elastic moduli and petrophysical properties are plotted. Two core samples were selected from Lu-5 well core 4 to conduct laboratory measurements for porosity and compare it with the results of porosity which calculated from Vs.

Keywords: ultrasonic, petrophysical properties

استخدام تقنية الموجات الفوق صوتية لحساب بعض الخواص البتروفيزياوية لنماذج اللباب التكويني الزبير والمشرف عند البئرين لحيس-5 وطوبة -5، جنوب العراق

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الخلاصة:

في هذا البحث، تمت دراسة سبعة عشر نموذج من اللباب الصخري والتي اخذت من البئرين النفطيين لحيس- 5 وطوبة -5 استنادا الى تواجد النفط في التكاوين المأخوذ منها النماذج. تقع منطقة الدراسة في محافظة البصرة / جنوب العراق . تضمنت النماذج تكويني الزبير والمشرف. وقد اختيرت النماذج من اعماق مختلفة . هذه الدراسة تتضمن استخدام الموجات فوق الصوتية لقياس السرع الطولية Vp و السرع القصية Vs بالاضافة الى حساب بعض الخواص البتروفيزياوية وكذلك معاملات المرونة (معامل يونغ ، معامل القص ، المعامل الحجمي ، نسبة بويزن و ثابت لامي) اعتمادا على قيم Vp ,Vs والكثافة. رسمت العلاقات بين سرع الموجات الزلزالية ومعاملات المرونة والخواص البتروفيزياوية المقاسة. تم اختيار نموذجين قد اختيرت من البئر لحيس-5 اللب 4 لحساب المسامية مختبريا ومقارنتها مع نتائج المسامية المحسوبة من السرع القصية Vs.

Introduction

Geophysical seismic surveys had been used widely for different important fields in order to identify the geology of the layers beneath the suggested sites that are considered as convenient locations for such engineering establishment, rocks nature and its bearing capacities are the main factors that must be taken into consideration during geophysical surveys [1, 2]. Ultrasonic Technique was used for this

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purpose. This technique was developed in subsequent years because of the need for detailed information about the quality of the rocks in evaluation of engineering processes as well as, to its necessary for the development of dynamic methods which includes a comprehensive study of the rocks [3]. The study area is shown in figure- 1.

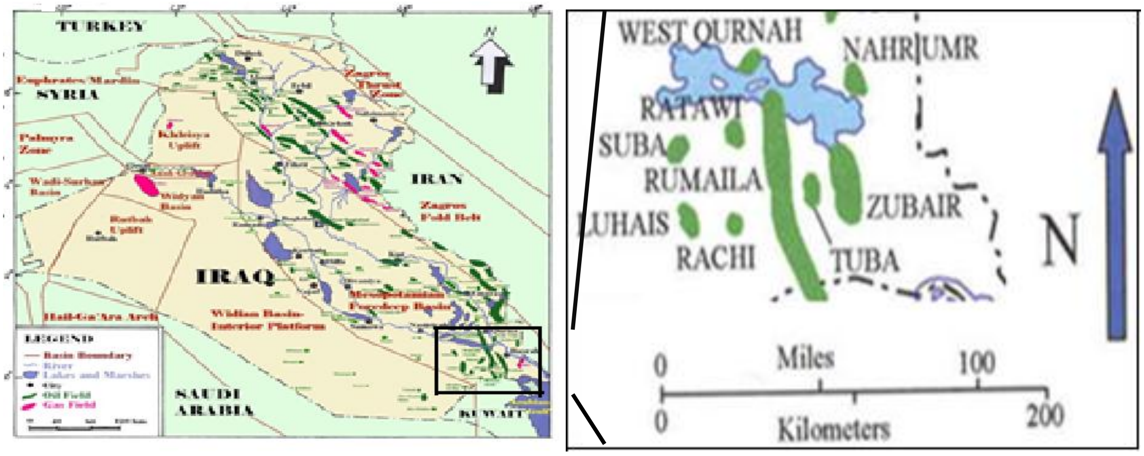

Figure 1- Location map of the study area[4].

Luhais oil field

Luhais oil field is located at about (50 km) south west of northern Rumaila oil field in Basra governorate, southern Iraq, between (47º,14′ – 47º,19′) longitude and $(30^0, 13' - 30^0, 24')$ Latitude. Many wells were drilling since 1973 and the Zubair Formation appears at depths (2777-3227)m figure-2.[5]

Tuba oil field

It is located at about (40 km) south west Basra governorate, between the Zubair oil field in the east and the Rumaila oil field in the west. It occurs at (5km) from Zubair field, and (2km) from Rumaila oil field figure-2. The structural setting of this field is elongated in direction NNW-SSE; its length at top of Zubair formation is about (26km) and its width (9km). Seismic surveys in 1977 showed that, the structural of the field includes two tops separated by a shallow saddle[6].

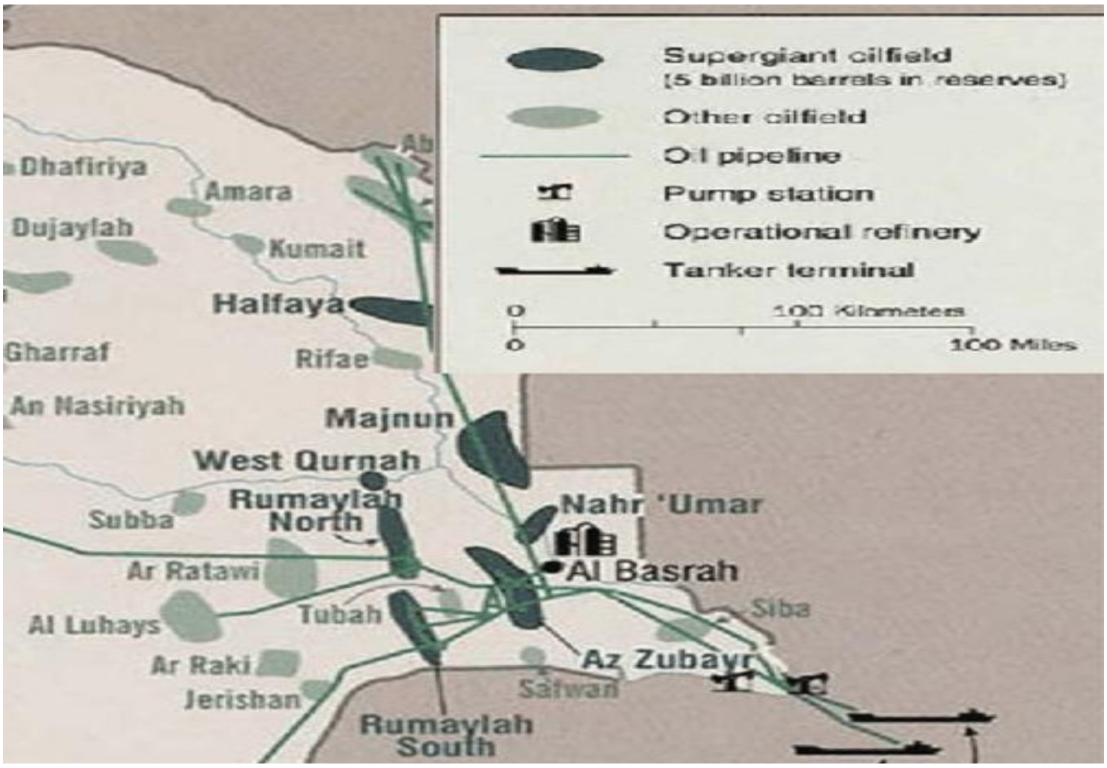

Figure 2- Oil field map [4].

Topography and Geology of the Study Area

The topography of study area is flat and semi desert, gradually reduce in the south direction to be at sea level, and the highest level is about (120m) above the sea level [7]. So it was located in unstable zone of Mesopotamian zone under Zubair subzone.

Zubair formation: Hauterivian - Early Aptian age

The formation belongs both in stratigraphy and economically to the most important formation of the lower cretaceous cycle in Iraq. It was introduced to designate the prevalently terrigenous clastic and oil bearing sequences of the southern Iraqi oil fields. The formation was given (according to Bellen et al, 1959) by Nasr and Hudson in 1953.The formation is essentially composed of alternating shales and sandstones with some siltstone. The type section has been divided into five divisions which are, from top to bottom [8].

a) Shale with two distinct zones of sandstones and minor amount of siltstones.
b) Predominating sandstones, with subsidiary shales and siltstones.
c) Black or greenish black shales, hard, with occasional sandstone streaks.
d) Predominating sandstones with subsidiary siltstone beds.
e) Greenish black shales with a sandstone- siltstone zone.

The variation in lithology displays some regularity. Towards the shore the amount of politic components rapidly decreases. Towards the basin the formation contains more and more shales and becomes almost pure shale near the dujaila area. The thickness of the formation in type area is about 380-400m. Towards the northeast the thickness increases up to 500m whereas towards the west and northwest decreases to roughly 200m and less. Zubair Formation represents a littoral, partly deltaic, sedimentary sequence composed of the products of erosion of Arabian shield and stable shelf which were uplifted during the late kimmerian movement. The age of the Formation, as determined on the bases of both fossils and regional correlation, is Hauterivian till early Aptian. [9]. It deposited during (LowerAptian – Hauterivian)age, its thickness about (420m),composed from sandstone ,shale and claystone**.**

Mishrif formation: Cenomanian - Early Turonian age

The Mishrif formation represents a heterogeneous formation originally described as organic limestones, with beds of algal, rudist, and coral reef limestones, capped by limonitic fresh water limestones[8,10] included all organic detrital neritic limestone units of Cenomanian Early Turonian age, such as M'sad, GirBir, and Mergi formations in Mishrif formation. Ditmar and the Iraqi-soviet team (1971) continued to recognize the GirBir and M'sad as separates formations. The Mishrif formation in its type area is composed of grey-white, dense, algal limestones with gastropods and shell fragments above, and of brown, detrial, porous, partly very shell and foraminiferal limestones, with rudist debris below. The Formation is variably dolomitized in west and NW of the type section. The formation was deposited as rudist shoals and path reefs over growing subtle structural high developing in an otherwise relatively deeper shelf on which open marine sediments of the Rumaila formation were deposed[11].So it is composite from calcite rocks growth in different sedimentary environments during upper Cenomanian, in general, present shallow sea. The formation thickness about (142m) and reduce at south field direction.

Aims of study

1. Determination of the elastic moduli and some petrophysical properties of core samples.
2. Determination of bulk porosities of core samples, using shear wave velocity.
3. To determine the relationships between the elastic moduli and petrophysical properties.

Methodology

The core samples must not be cut with a length less than 10 cm. for measuring the velocities for both of Vp and Vs by using new sonic viewer, also measuring the densities of the above core samples to calculate the dynamic and geotechnical properties, as well as porosities of these rocks from the velocity of S-wave. The new sonic viewer send electric pulses that are transfer to mechanical waves in transmitter and received by receiver which transfer these waves to electrical pulses and showing them on CRT as sinusoidal waves [12].

Theoretical Background

The seismic wave is the basic measuring rod used in seismic prospecting. If we are to understand how it works and evaluate the information we get from it in geological terms, we must be familiar with the basic physical principles governing its propagation characteristics. These include its generation, transmission, absorption, and attenuation in earth materials and its reflection, refraction, and different characteristics at discontinuities [13]. The property of resisting changes in size or shape and returning to the undeformed condition when the external forces are removed is called elasticity [14]. Seismic waves are generally referred to as elastic waves because they cause deformation of the material in which, the propagation like that in an elastic band when it is stretched. [13]. Seismic wave is acoustic energy transmitted by vibration of rock particles [15].

Compression wave (P – wave)

These waves generally travel faster than secondary waves and can be travel through any type of material.[13, 16]

It expressed by these equations:

$$V_p = \sqrt{\frac{E(1-\nu)}{t(1+\nu)(1-2\nu)}} \qquad (1)$$

Where

ρ : Density E : Young's modulus σ : Poisson's ratio

Transverse waves (Shear waves)

Transverse wave is slower than P-wave in solid. Shear waves have not travel through the liquid[17]. It was called shear waves [13, 18].It expressed by :

$$Vs = \sqrt{\frac{E}{2\rho(1+\sigma)}} \qquad (2)$$

Factors affecting seismic wave

The velocities of seismic waves depend mainly on the elastic properties of the minerals making up the rock itself.[13]. There are several factors that have significant effect on the propagation of seismic waves Vp&Vs through rocks. These factors are density, lithology, depth, age, joints and fractures, texture, frequency, pressure and temperature, anisotropy and saturation.

Elastic Constants

A ccording to Hook's law a strain is directly proportional to the stress producing it. The relationship between stress and strain was expressed as elastic constant, these constants explain the rock properties, and these are: ([19, 20, 21].

1. Young's modulus(E)

It is longitudinal stress divided by longitudinal strain [13]. The dynamic Young's modulus is given in the following eqation:

$$E = \frac{\rho V_p^2(1+\sigma)(1-2\sigma)}{(1-\sigma)} \qquad \text{......... ..... (3)}$$

Expressed by Nt/m2=Pascal

2. Bulk Modulus (K)

It is deformation in body volume without changing in its shape.[13]

It expressed in this equation :

$$K = \rho(V_p - \frac{4}{3}V_s) \qquad \text{............... (4)}$$

It expressed by Nt/m2 =Pascal

The inverse of K is called compressibility (β), it is expressed in equation:

$$\beta = 1/K \qquad \text{............... (5)}$$

3. Shear modulus or rigidity (μ)

It is deformation in body shape without changing in its volume, so present proportion between shear stress and shear strain. The value of shear modulus ranged between (10×10^3-7×10^4) Mpa in rock material. [21], shear modulus equal zero for liquid and gas. [22].

It expressed by Nt/m2 =Pascal

$\mu = \rho V_s^2$ ……………… (6)

4. Poisson's ratio (σ)

It is representing as relation between the transverse strain and the longitudinal strain whether the stress is compressive or tensile [22, 23, 24].

It is expressed in the following equation:

$$\sigma = \frac{(\frac{V_P}{V_s})^2 - 2}{2(\frac{V_P}{V_s})^2 - 2}$$ …………….. (7)

5. Lame's constant (λ)

Is a scale of material strength, it is valid for isotropic media i.e. media in which the elastic properties are independent of direction [23]. Lame's constant (λ) is the same as shear modulus (μ) , in perfect elastic condition when Poisson's ratio is equal 0.25 , these constants (**λ**) and (**μ**) are equal .

It is expressed in the following equation:

$\lambda = \rho(V_p^2 - 2V_s^2)$ …………….. (8)

Field work and Instrumentations

The field work is made in geological workshop in the core rock packages in Iraqi southern oil company, after selecting, prepare the core, the samples were numbered and marked to their tops and bottoms, then smoothing the faces.

The arrival time of P and S waves measurement was taken by the following steps:

1. Cutting the samples by parallel faces, and their lengths were not less 10cm.
2. Smoothing the faces by grinding paper to get good coupling with receiver and transmitter of ultrasonic instrument.
3. Measuring the transit time for both P and S waves (P- wave is taken by putting sample between receiver and transmitter after putting the vaseline on sample faces) by using their transducers after calibrating the instrument , then powered enhance adjust to recognize the first arrival point of the wave. The shift adjustment use to matching the start of arrival time of wave with vertical axis and take the reading that appear on bottom of the screen which present time of wave transmit through sample (micro sec). then calculating the velocities of longitudinal and transverse waves from these equation :

Vp = L/Tp …………………. (9)

Vs = L/Ts …………………. (10)

Tp, Ts: Transmitted time (P or S waves)

L: Length of core sample

4. Measuring the length of each core sample with their diameter to get their volumes, because all samples are geometrical in shape.
5. Weighing the samples by electronic balance with an accuracy of (1gm).

Density measurement

The density of core samples (ρ) is calculated by traditional way, by calculating samples volume and weight. The density was calculated using the following equation:

$$\rho = \frac{sample\ weight}{sample\ volume}$$ ……………… (11)

Porosity measurement

Pickett, 1963 in Domenico, 1984 suggested empirical equation to determine the porosity depending on seismic velocities: [25, 26, 27]

$\frac{1}{V} = A + B\emptyset$ ……………..(12)

V: velocity (Vp or Vs)

A,B: constants

Ø : porosity

A: (291.967) for sandstone B: (54.601983) for sandstone

A: (213.79) for limestone B: (59.62) for limestone

Instruments

Many instruments were used in this work field such as

1. OYO's NEW SONICVIEWER (model-5217A) to determine velocity measurements of rock samples.
2. Cutter for cutting the core samples with parallel faces.
3. Electronic balance for measuring the weight of samples of accuracy 1gm and maximum of 7 kg.

Laboratory measurements:

Longitudinal and transverse wave velocities

The velocity of seismic waves (Vp and Vs) determined from transmitted time of the waves by the equations (9) and (10), respectively.

Porosity determination:

The empirical equation (12) used to calculate the porosity from S-wave velocity after calculating the constants A and B, at depths greater than (4000m) with differential pressure (PSI) approximately equal (9000 PSI) as shown in the following table:

Table 1- The constants A and B.

S – wave				
Limestone		Sandstone		Pressure
A constant	B constant	A constant	B constant	
291.967	54.601	213.79	59.62	9000

A liquid saturation method is used to determine the porosity in laboratory for (2) samples of Lu-5 C4.

1. The dry weight of sample is measured using a sensitive balance.
2. Saturate the sample in known density liquid (used water in this laboratory test) not less than (24) hours.
3. The saturated weight of each sample is measured after (24) hours.
4. The deference in weight between saturated and dry samples are calculated, and divided by the density value of water (1gm/cm3) to get the pore volume, which is given in this equation:

$$V_{po} = \frac{W_s - W_d}{water\ density} \qquad (13)$$

Vpo: Pore volume
Ws: Saturation sample weight
Wd: Dry sample weight
Water density = 1gm/ cm3

5. Bulk volume is determined by calculating the difference between the volume of liquid before and after immersing sample inside the liquid.
6. The porosity is calculated using this equation:

$$\frac{1}{V} = A + B\phi$$

Results and Discussions

Luhais oil well NO.5 core 4:

Eight core samples were taken from this core of depth (2779-2783)m distributed with different intervals because of their length which must not be less than 10cm. The core samples are sandstone which belongs to the Zubair formation.

The values of P - wave velocities of core samples in this well range between (1812- 4094 m/sec) and its average is (3188m/sec).

The values of S - wave velocities of core sample in this well range between (877- 1960 m/sec), and its average is (1449m/sec).

Depending on the results of P-wave and S-wave velocities, the relationship for these samples is plotted as shown in figure-3. The relationship is given in the following equation:

Vs = 0.4482Vp + 20.89

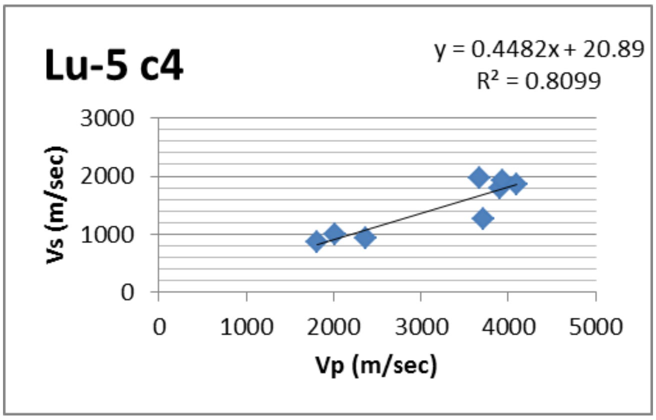

Figure 3- The relationship between P and S wave velocities.

The average of porosity in these samples is (9.2%). The relationship between S-wave velocities and porosities is shown in figure- 4. The resulting relationship is given in the following equation :

$Ø = 0.0168\ (1/Vs) - 3.5859$

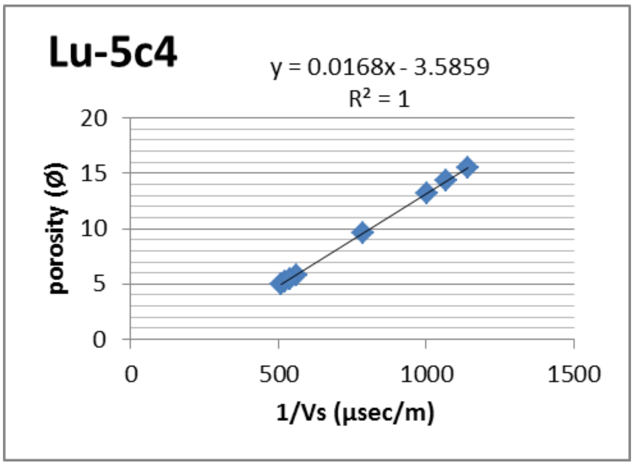

Figure. 4-The relationship between Vs and porosity.

The densities of core samples range between (1002-2885) kg/m^3, and their average is (1730) kg/m^3. The relationship between P - wave velocities and density is shown in figure- 5a, also the relationship between S - wave velocities and densities is shown in figure -5b. The resulting relationships are given in the following equations:

a) $Vp = 1.133\ \rho + 1090.5$

b) $Vs = 0.5188\ \rho + 551.53$

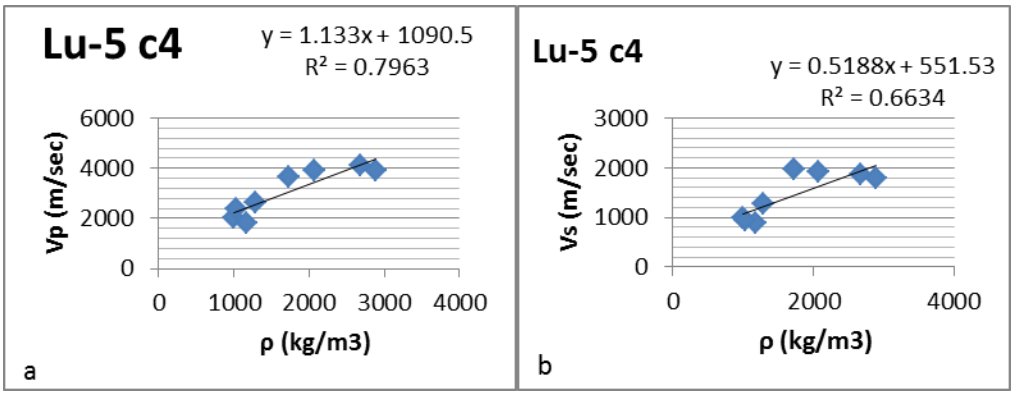

Figure.5-a) The relationship between the densities and Vp, b) The relationship between the densities and Vs.

Young's modulus of core samples is determined by using the equation (3). The values of Young's modulus range in these core samples between (2.425 - 25.29) GPa, and their average is (12.663) GPa.

The relationship between Young's modulus and P-wave velocities of core samples is shown in figure-6a, also the relationship between Young's modulus and S-wave velocities is shown in figure-6b .The resulting relationships are given in the following equations :

a) E=0.0106 Vp -19.777

b) E=0.0203 Vs -16.781

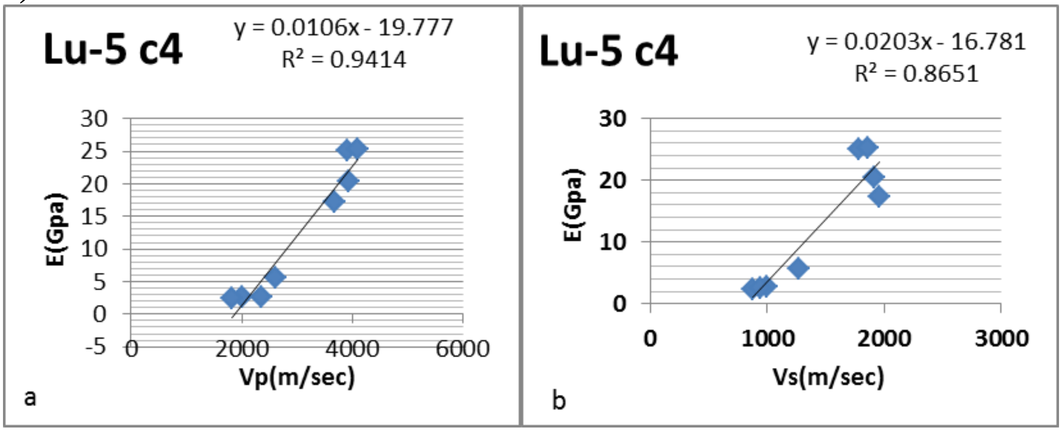

Figure.6- a) The relationship between Vp and Young's modulus; b) The relationship between Vs and Young's modulus.

The shear modulus of core samples is determined by using the equation(6). Shear modulus values range in these core samples between (0.9 -9.224) GPa, and their average is (4.687) GPa. The relationship between the shear modulus and P-wave velocities is shown in figure-7a, also the relationship between the shear modulus and S-wave velocities is shown in figure-7b, and the resulting relationships are given in the following equations:

a) μ= 0.0039 Vp - 7.2929

b) μ= 0.0076 Vs-6.2624

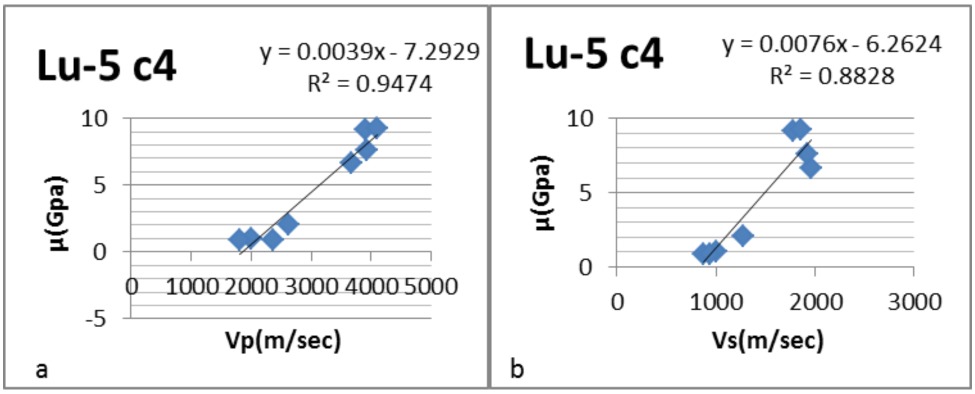

Figure.7- a) The relationship between Vp and shear modulus; b) The relationship between Vs and shear modulus.

Bulk modulus is determined by using the equation (4). Bulk modulus values range in these core samples between (2.644 - 32.628) GPa, and their average value is (14.594) GPa. The relationship between Bulk modulus and P-wave velocities is shown in figure-8a , also the relationship between the S- wave velocities and Bulk modulus is shown in figure-8b. The resulting relationships are given in the following equations:

a) K = 0.0124 Vp - 23.24

b) K =0.0224 Vs - 17.828

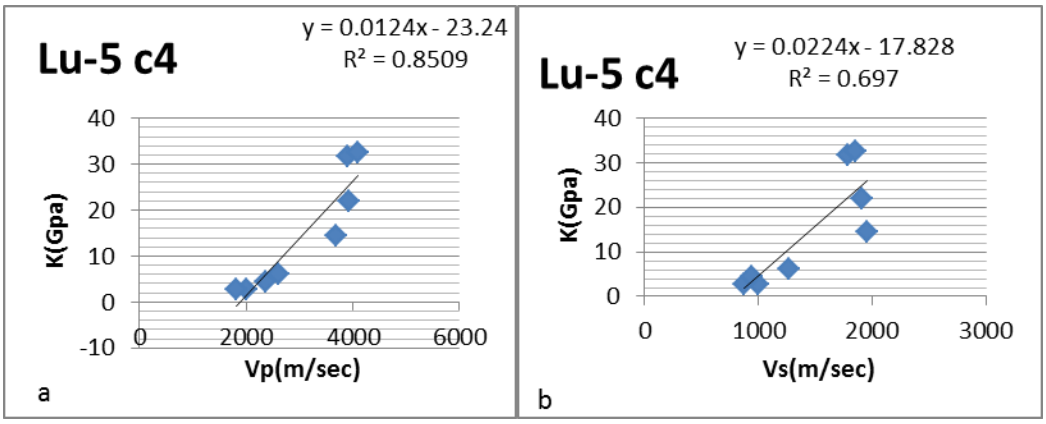

Figure.8- a) The relationship between Vp and Bulk modulus; b) The relationship between Vs and Bulk modulus.

Poisson's ratio is determined by using equation (7) for determining the value of dynamic Poisson's ratio. Poisson's ratio values range in these core samples between (0.301- 0.406), and their average is (0.352). The relationship between Poisson's ratio and the Vs /Vp ratio is shown in figure-9. The resulting relationship is given in the following equation:

$Vs/Vp = -1.2972\ \sigma + 0.9315$

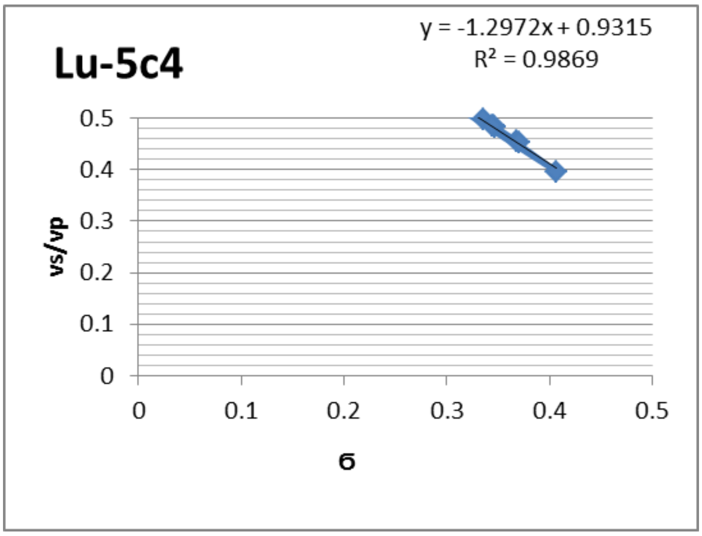

Figure.9-Relationship between Vs /Vp ratio and Poisson's ratio.

Lame's constant is determined by using equation (8) for determining the value of dynamic Lame's constant. Lame's constant values range in these core samples between (2.044-26.478) GPa, and their average is (11.469) GPa. The relationship between Lame's constant and P-wave velocities is shown in figure-10a , also the relationship between S- wave velocities and Lame's constant is shown in figure-10b. The resulting relationships are given in the following equations:

a) $\lambda = 0.0098\ Vp - 18.378$

b) $\lambda = 0.0173\ Vs - 13.653$

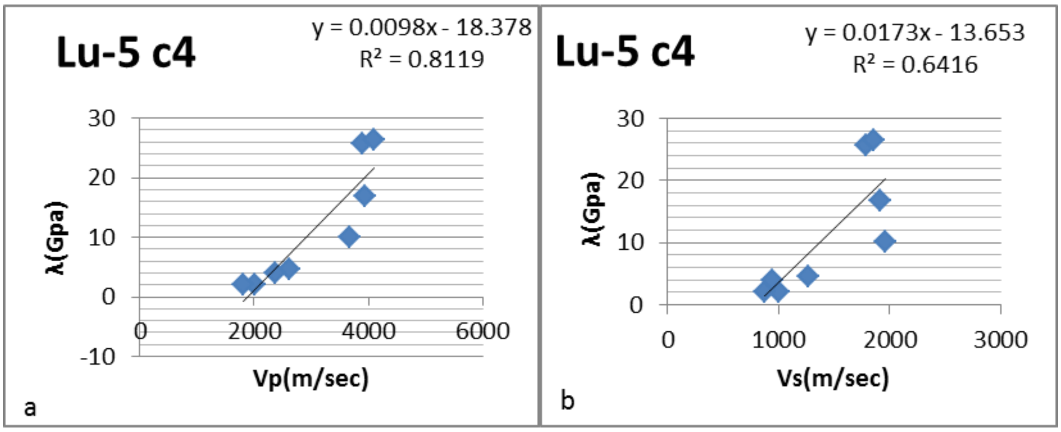

Figure 10- a) Relationship between Vp and Lame's constant; b) Relationship between Vs and Lame's constant.

The relationship between Vp/Vs and K/μ is very important[28], because one can separate the weak zones, when the S-wave velocity is low and P-wave velocity is high.
The values of (Vp / Vs) ratio range in these core samples between (1.875 - 2.521), and their average value is (2.123).
The (K / μ) ratio values ranges in these core samples between (2.182 - 5.025) , and their average value is (3.207). The relationship between the two rates above is shown in figure-11, and the resulting relationship is given in the following equation :
$k/\mu = 4.4288 (Vp/Vs) - 6.1967$

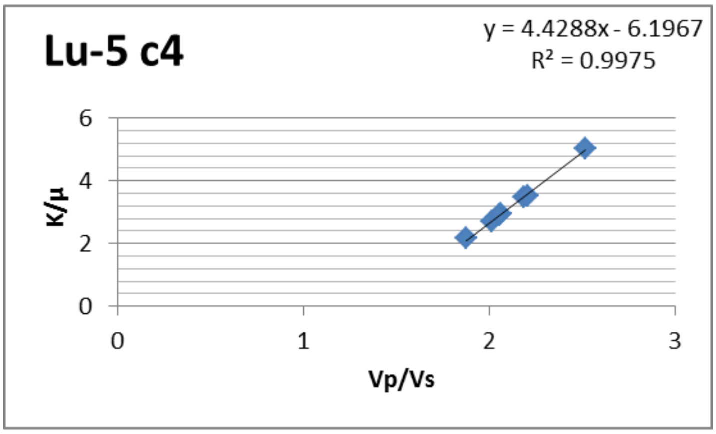

Figure 11-Relationship between the (Vp / Vs) and (K / μ).

Tuba oil well NO.5 core5:
Nine core samples were taken from this core from of depth (2416-2423)m distributed with different intervals because of their length. The core samples are limestone which belongs to the Mishrif formation.
The values of P - wave velocities in these core samples range between (3150- 6342m/sec), and the average is (4595m/sec), and the values of S - wave velocities in these core samples range between (1111- 2854m/sec), and the average is (1898m/sec). Depending on the results of P-wave and S-wave velocities, the relationship for these core samples is plotted which shown in figure-12. The resulting relationship is given in the following equation:
$Vs=0.5035\ Vp- 396.75$

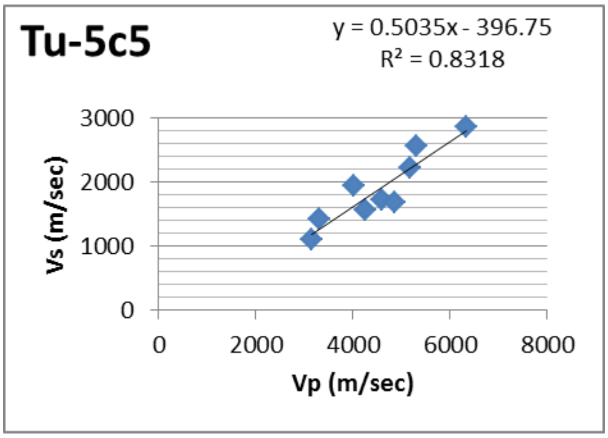

Figure.12- Relationship between Vp and Vs.

The average porosity of these core samples is (5.07%). The relationship between S-wave velocities and porosities is shown in figure-13, and the resulting relationship is given in the following equation
$ø = 0.0183\ (1/Vs) - 5.3472$

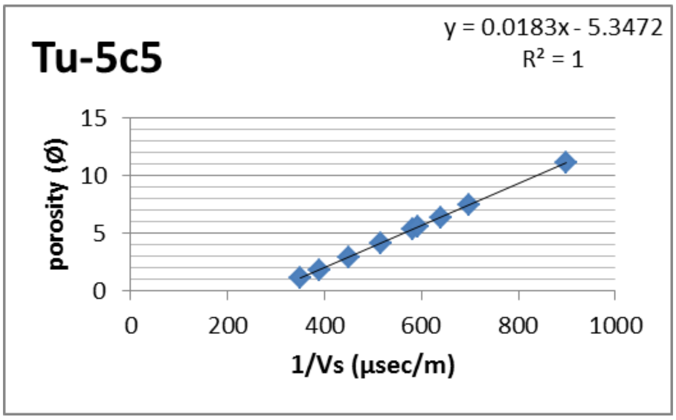

Figure.13-Relationship between Vs and porosity.

The densities of core samples are calculated, and its values range between (2304- 2719) kg/m^3, and the average is (2441) kg/m^3.The relationship between P - wave velocities and density is shown in figure-14a, also the relationship between S - wave velocities and densities is shown in figure-14b. The resulting relationships are given in the following equations:

a) $Vp = 2.5937\ \rho - 1775$

b) $Vs = 1.224\ \rho - 1090.2$

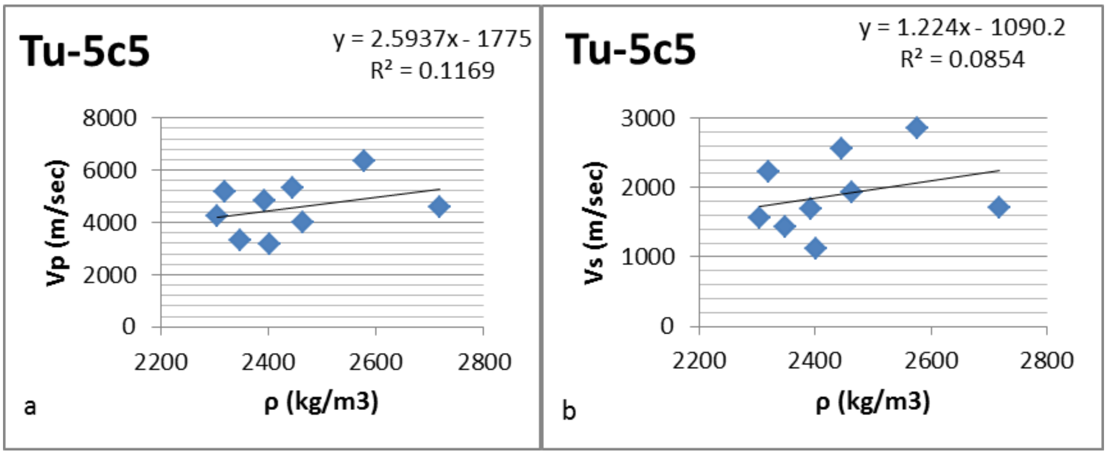

Figure.14-a) Relationship between the densities and Vp., b) Relationship between the densities and Vs.

The values of Young's modulus of these core samples range between (8.47 - 57.66) GPa and the average is (26.426) GPa. The relationship between Young's modulus and P-wave velocities of core samples is shown in figure-15a , also the relationship between Young's modulus and S-wave velocities is shown in figure-15b. The resulting relationships are given in the following equations:

a) $E = 0.0141\ Vp - 37.904$

b) $E = 0.0276\ Vs - 25.908$

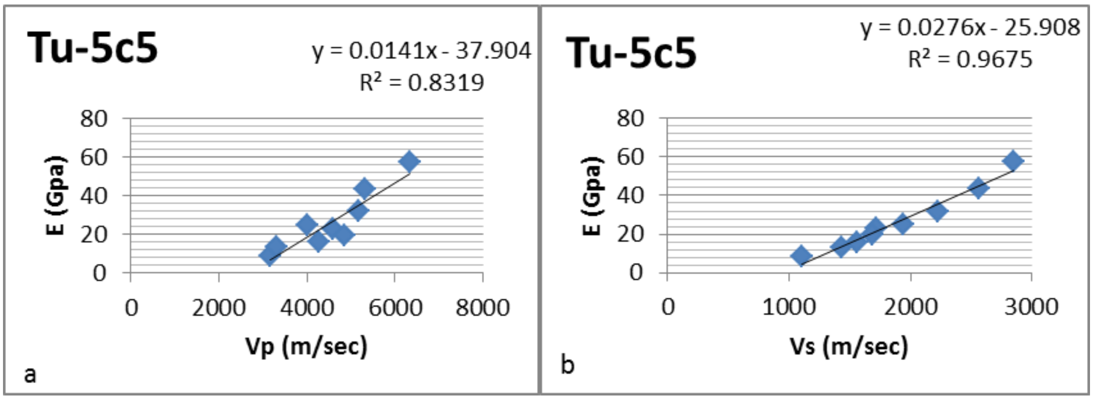

Figure.15-a) Relationship between Vp and Young's modulus, b) Relationship between Vs and Young's modulus.

Shear modulus values ranged in these core samples between (2.966 - 20.997) GPa and the average is (9.558) GPa. The relationship between the shear modulus and P-wave velocities is shown in figure-16a, also the relationship between the shear modulus and S- wave velocities in figure-16b. The resulting relationships are given in the following equations:

a) $\mu = 0.0052\ Vp - 14$

b) $\mu = 0.0102\ Vs - 9.8406$

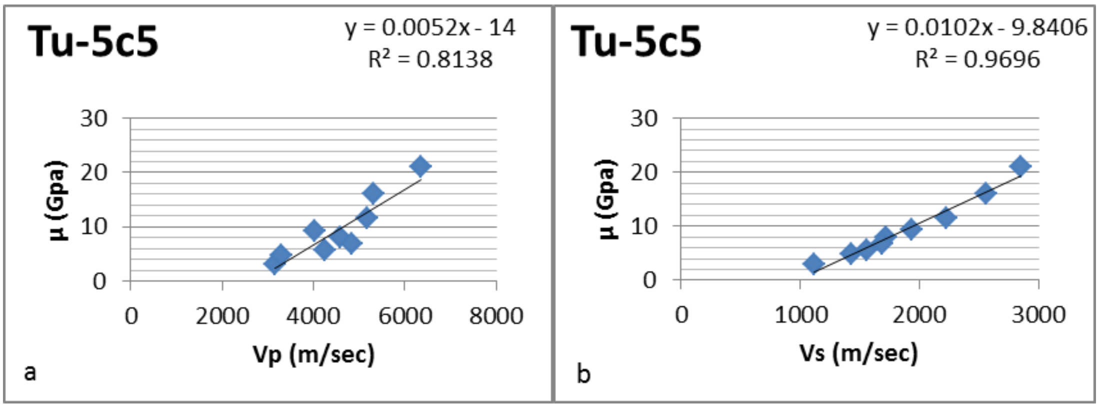

Figure.16-a) Relationship between Vp and shear modulus, b) Relationship between Vs and shear modulus.

Bulk modulus values ranged in these core samples between (19.145 - 75.693) GPa, and the average value is (40.604) GPa. The relationship between Bulk modulus and P-wave velocities is shown in figure-17a , also the relationship between S- wave velocities and Bulk modulus is shown in figure-17b. The resulting relationships are given in the following equations:

a) $k = 0.017\ Vp - 37.018$

b) $k = 0.0264\ Vs - 9.445$

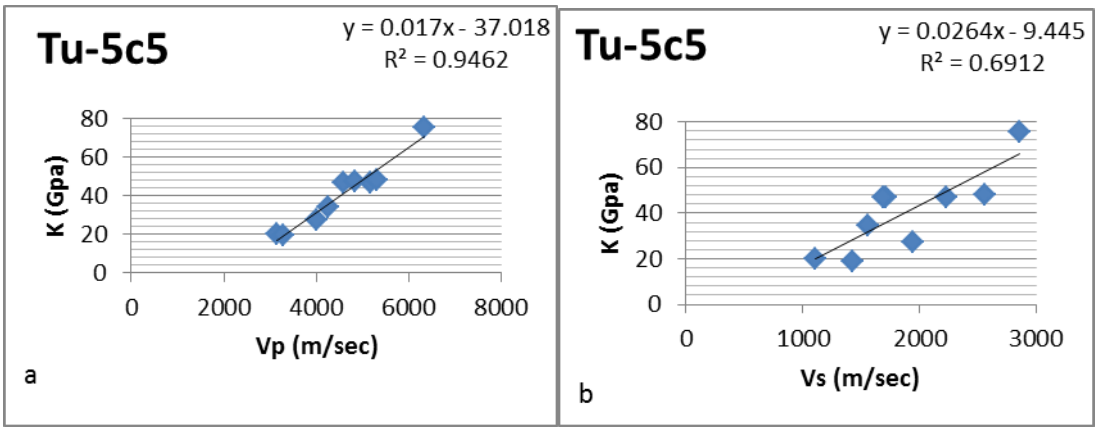

Figure. 17- a) Relationship between Vp and Bulk modulus, b) Relationship between Vs and Bulk modulus.

Poisson's ratio values range in these core samples between (0.348 - 0.431) and the average is (0.393). The relationship between Poisson's ratio and Vs /Vp ratio is shown in figure-18. The resulting relationship is given in the following equation :

Vs/Vp= -1.6268 σ + 1.0535

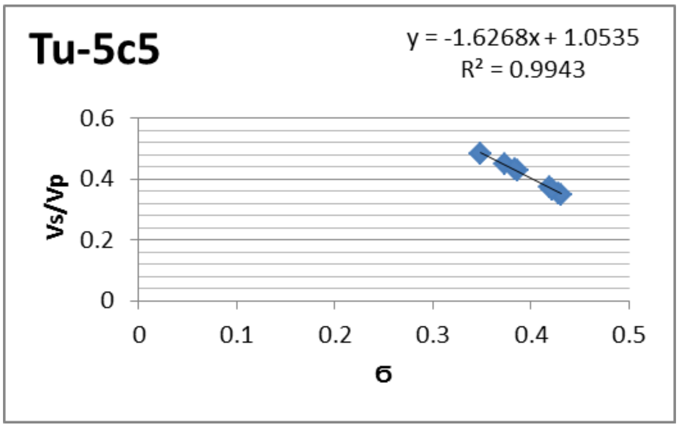

Figure.18- Relationship between Vs /Vp ratio and Poisson's ratio.

Lame's constant values are ranged in these samples between (15.939 - 61.695) GPa, and the average is (34.232). The relationship between Lame's constant and P - wave velocities is shown in figure-19a , also the relationship between S - wave velocities and Lame's constant is shown in figure-19b. The resulting relationships are given in the following equations:

a) λ = 0.0136 (Vp) - 27.684

b) λ = 0.0195 (Vs) - 2.8846

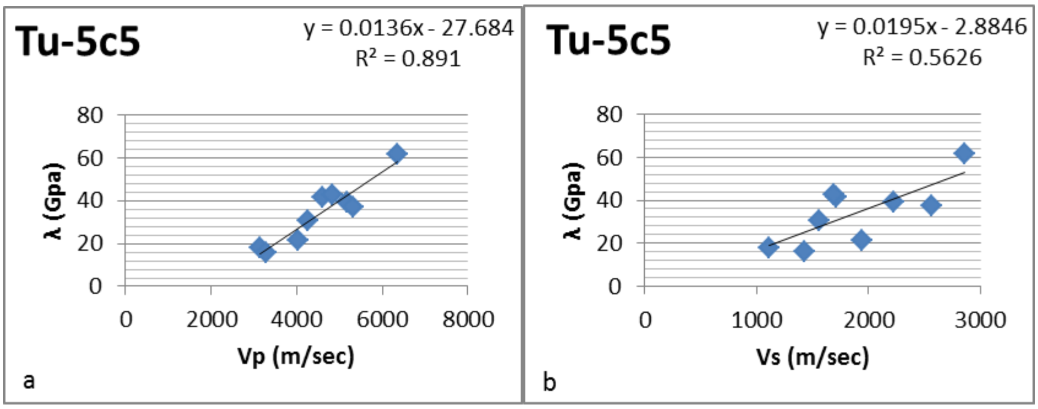

Figure.19- a) Relationship between Vp and Lame's constant;b) Relationship between Vs and Lame's constant.

The values of (Vp / Vs) ratio range in these core samples between (2.0727 - 2.8787) , and the average value is (2.458). The (K / μ) ratio values range in these core samples between (2.96 – 6.95),and the average value is (4.803).The relationship between the two rates above is shown in figure-20. The resulting relationship is given in the following equation :
$k/\mu = 4.9486 (Vp/Vs) - 7.3628$

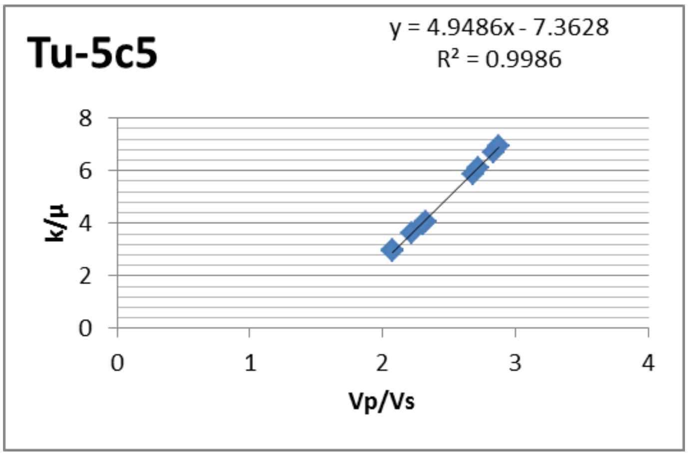

Figura. 20- Relationship between the (Vp / Vs) and (K / μ).

Conclusions

Seismic velocities of P and S waves for core samples are measured, and the range of Vp is (1812-4094 m/sec),and the range of Vs is (877-1960m/sec) for Lu-5 c4, the range of Vp is (3150-6342m/sec), and the range of Vs is (1111-2854m/sec) forTu-5 c5.

The measurements of P and S waves for some samples showed that, clear vacillation and a wide range of the seismic wave velocity values, and this is caused by the presence of fractures and cracks, as well as the pores and difference in lithology, where the presence of the clay has its impact on velocities which leads to a decrease in velocities of seismic waves.

1. Elastic moduli are calculated using the seismic wave velocities of (Vp and Vs) as well as the densities. The results of these transactions are shown in table-2.

Table 2- The averages of elastic moduli values of core samples in oil well.

Well No	E(Gpa)	μ(Gpa)	K(Gpa)	λ (Gpa)	σ
Lu-5-c4	12.6633616	4.68796884	14.5947101	11.4693976	0.3526
Tu-5-c5	26.4269521	9.5582985	40.6046298	34.2324308	0.3936

2. The porosities of core samples are calculated from shear wave velocities, because Vs is more sensitive to changes in porosity than Vp [26].The averages and ranges of porosities for each well are shown in table -3.

Table 3- The averages and ranges of porosity of core samples in oil well.

Well No.	Porosity average %	Porosity range %
Lu-5-c4	9.26%	4.97 – 15.53
Tu-5-c5	5.07%	1.06 – 11.13

The results of porosity showed that there is a wide range of values per core and this is due to several reasons, including the presence of fractures and pores as well as the covariance in lithology in some samples

The results of porosity of two samples which calculated from the velocities of transverse waves (Vs) showed that the values are close to the values of porosity calculated laboratory, as shown in table- 4.

Table 4- Porosity values for two samples which are calculated in Lab..

Well No.	Sample No.	Porosity (Vs) %	Lab. Porosity %
Lu-5-C4	7	5.1	3.7
Lu-5-C4	8	5.4	3.8

3. The ranges of densities of core samples for each well are shown in table-5.

Table 5- The ranges of density of core samples in oil well.

Well No.	The density range (kg/m^3)
Lu-5-c4	1002 – 2885
Tu-5-c5	2304 – 2719

The results of density showed that there is a wide range of values at some core sand this is due to several reasons, including that, the presence of fluids (oil) in pores as well as the covariance in lithology in some samples.

4. The relationships between [(Vp and Vs), (ø and Vs), (Vp and ρ), (Vs and ρ), (E,μ,K,λ and Vp) and (E,μ,K,λ and Vs)] in all cores of the studied area, show that they are directly proportional to each other , but the relationship between Poisson's ratio and Vs/Vp is an an inverse one .

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